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ON A NEW ODONTOGRAPH.

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THE WILLIS ODONTOGRAPH.

THOSE who have used, or even studied the *Odontograph* of Professor Willis, of Cambridge, England, cannot be otherwise than forcibly impressed with the admirable simplicity and great utility of the instrument. Indeed, it has attained to such general favor that it is not only in the hands of a large proportion of the constructors of mill gearing in Europe and America, but in every work of importance on Cinematics, Principles of Mechanism, Machinery and Millwork, &c., published since its discovery in 1838. In fact, the instrument is worthy of a place in the tool chest of every millwright and machinist; particularly those who have no better understanding of the mode of delineating gear teeth, than to use, for generating the faces of teeth with radial flanks, describing circles which are the opposite pitch circles themselves, instead of circles one-half as large.

Although the teeth of wheels, laid out by the aid of the odontograph, are only approximately correct, such teeth are not very far from correct working forms. This fact was practically demonstrated to the writer at the justly-celebrated machine factory of Wm. Sellers & Co., of Philadelphia, where a pair of heavy cut gears were seen in action, running with extraordinary quietness. On inquiry as to the remarkable working quality of these gears, it was stated that the cutters were made expressly for them in strict conformity with the Willis odontograph; which, in the present instance, it is fair to suppose, was an experiment to test the odontograph teeth, as compared with those laid down correctly by theory. Teeth formed thus carefully, even though they be only approximate, are much to be preferred to the rattling, guess shapes; and amply repay the trouble required to secure them. It is therefore much better, in cases where the theory of gearing is not understood, to resort to an odontograph, than to jump blindly at a rattle trap.

For example: a common form among millwrights is obtained by taking the middle point of a tooth at the pitch line for a center, and describing, by arcs of circles, the nearest flanks of the next adjacent teeth, and the further faces of the same two teeth. Describing, thus four arcs from the center of each tooth, all the faces and flanks are laid out. This gives flanks which are concave, with radii which are less than those of the convex faces, while the opposite relation is known to be required in correctly laid

out teeth. This rule probably gives shapes which are worse than mere guess shapes.

A GOOD ODONTOGRAPH DESIRABLE.

The delineation of correct working gear teeth according to theory for individual cases is a very easy matter when the method is understood, but not so easy as to use a convenient odontograph; and hence, a good odontograph is advantageous to all designers of gearing.

ESSENTIAL QUALITIES OF A GOOD ODONTOGRAPH.

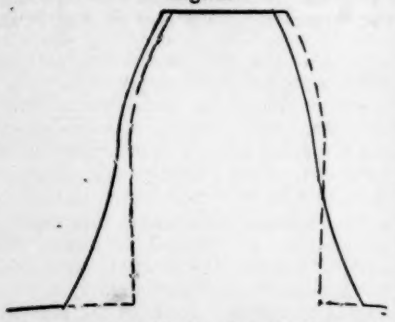
An odontograph, to give the highest satisfaction, should be one which leaves nothing to be desired; neither in the degree of approximation, nor the general form of tooth it gives.

Those who have employed the odontograph of Prof. Willis, cannot fail to have noticed that in wheels of many teeth the form is very different from that obtained by laying out the teeth of the epicycloidal form with radial flanks,* which form is the most common and usually the most acceptable. Also the odontograph must be simple, and easy of application.

PECULIARITIES OF THE WILLIS ODONTOGRAPH TOOTH.

A tooth of a wheel of eighty teeth, as laid down by aid of the Willis odontograph, is shown in Fig. 1; and also, a

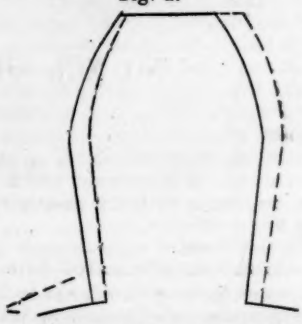
Fig. 1.



little to one side in dotted lines, the same tooth of epicycloidal form with radial flanks, as calculated to work with a second wheel of twelve teeth. The clearance curves are not put in. The odontograph tooth exhibits very marked peculiarities, a noticeable one being the greater general inclination of the side of the odontograph tooth to the radius of the wheel; giving rise to unnecessary obliquity of action, and consequent mutual crowding of the wheels against their shafts.

Prof. Willis limits his odontograph to twelve teeth for the least number, and for this the teeth have radial flanks as shown in Fig. 2, which works with a

Fig. 2.



wheel of eighty teeth. This limitation causes the teeth of small wheels to be narrow at the base, and of large wheels to be unnecessarily wide. In wheels having a not unusually large number of teeth, the flanks start out from the pitch line towards the center with a divergence from each other approaching 30°.* In other words, the odontograph teeth approach the narrowness of base of epicycloidal teeth with radial flanks when the latter are objectionably narrow, as in wheels of few teeth; and much wider, indeed excessively wide, when, for the same wheels, epicycloidal teeth are of good form. Also a marked peculiarity, as exhibited in Fig. 2, is the decided angular junctions of the flanks and faces.

RESTRICTION OF THE WILLIS THEORY, AND MODIFIED FORM OF ODONTOGRAPH.

These undesirable features are, however, in the main, no fault of the general theory of Prof. Willis for the formation of teeth with circular arcs, but appear to be due to restrictions imposed, for the purpose of simplifying the tables

* When these teeth would appear too weak at the root or base, *clearance curves* are usually struck in, or curves between the flanks which the points of the teeth of the opposite wheel will just clear, up to which the roots of the teeth may be thickened for the purpose of greater strength.

* See Fairbairn, Mills and Millwork, Part II, Plate IX, Fig. 1. A. Lambert, Cinematique, Pl. 14.

for, and application of, the odontograph itself. The restrictions which contribute mostly to this are the fixed angle of 75°, and the constant length, relatively to the pitch, of the perpendicular to the line of action. By restricting the theory in a different manner, a certain modification of the instrument and its application may be effected, which gives straight and more nearly radial flanks for all wheels, and circle arc faces. This will be treated further on.

NEW FORM OF ODONTOGRAPH.

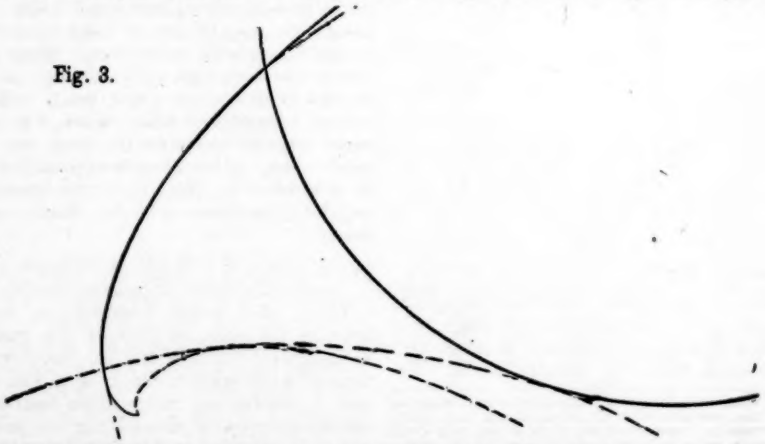
For those who will adopt nothing which is so incomplete as a circle arc for a tooth face, but will lay down the correct curves; and for even the less theoretical who would prefer to accept a good practical *short-cut* to a correct result than to go by guess; I would offer the new odontograph, which is now to be described: an instrument which in no circle arc, mode or form, resembles any thing above referred to.

This new form of odontograph is not only adapted to give radial flanks, but faces which agree with almost undiscoverable nearness with the epicycloidal face. The face curve, as laid down by the instrument, is exactly normal to a tangent to the pitch line drawn from the middle point of a tooth, and it intersects the addendum circle precisely where the true epicycloidal curve proper to the tooth in question does.

Now, as the pitch line and its tangent, pass either way from the middle of the tooth, they depart from each other slightly in distance, and more so in direction. A circle arc, approximating to a tooth face, will generally have a radius considerably greater than the half thickness of a tooth: but for a circle arc to be normal to the above-named tangent and to the pitch circle at the side of a tooth, both at the same time, its radius must be much less than the half thickness of a tooth, as is evident on inspection; and hence, the circle arc cannot osculate closely with the epicycloid, and at the same time be normal to the pitch circle, as Figs. 1 and 2 show. The most closely osculating curve must, therefore, be one which rapidly changes curvature; and such a curve will be very nearly normal to the above mentioned tangent to the pitch circle.

The odontograph should, therefore, give a curve which changes curvature rapidly. Now, as the epicycloidal curve is normal to the pitch line, and very nearly so to the tangent to the pitch circle drawn from the middle of a tooth, it is clear that if a curve of rapidly changing curvature be so placed as to be normal to the tangent, as above described, and at the same time intersecting the addendum circle at the same point that the epicycloidal curve required for the tooth considered does, it will represent the epicycloidal tooth face with great precision. This truth is rendered apparent to the eye in Fig. 3, in

Fig. 3.



which the full line is the odontograph curve, and the dotted line the required epicycloid. The flanks are also drawn in to give an idea of the conformity of

the whole tooth, as delineated by aid of the instrument, with the true epicycloidal tooth. These teeth belong to a wheel, the pair of which are of equal size. The object of making the curve perpendicular or normal to the tangent, as above described, instead of the pitch circle, is to render the odontograph more convenient of application; and it is found that the curve selected, in the manner hereafter explained, meets the radius for extending the side of the tooth into the flank with an error of tangency, which is too small to be readily detected.

With these explanations, it becomes evident that the leading propositions of the new odontograph are:

1st. That it give a curve of rapidly changing curvature, having the closest possible osculation with the epicycloid, and at the same time be of general application.

2d. That the curve for a tooth face, given by the instrument, be normal to a tangent line to the pitch circle at the middle of a tooth.

3d. That this curve intersect the addendum circle precisely where the epicycloidal curve proper to the tooth in question does.

FORM OF CURVE ADOPTED.

The curve adopted as conforming most closely, in general, with limited initial portions of the epicycloid, is the *logarithmic spiral.*

This curve appears to possess the highest degree of adaptation, because of its uniform rate of change of curvature, and also because this rate can be assumed at pleasure.* Furthermore, the analytical relation of this spiral to the problem is simple.

FORM AND APPLICATION OF INSTRUMENT.

In planning this odontograph, the leading endeavor was to make its practical application the most convenient possible, without a sacrifice from accuracy of form of tooth obtained by it.

That the reader may learn the leading features of the instrument before proceeding to the details of its demonstration, its form and mode of application will first be explained.

The odontograph is shown full size in Fig. 4, as of suitable capacity for laying out all teeth below six inches pitch. Its capacity, however, is extended to any degree by simply prolonging the curved edges. It should be made of metal, because it is intended that the instrument, when desired, may be used directly for a scribe template, in which use it will be subject to wear from the passes of the scribe. It has several holes countersunk on both sides as shown at H, so that it may be attached by wood screws, or by bolts expressly prepared, to any convenient wooden rod, in such a manner that when the rod swings around a center-pin to the wheel, all the faces of the teeth may be described directly from the instrument itself. The desired result is thus obtained directly without intervening center points and dividers.

In this manner the odontograph becomes a general template, and equally valuable for guiding the draughtsman's right-line pen, or the pattern maker's steel scribe.

To place the instrument in position for drawing a tooth face, a table is used which should accompany the instrument. From this table a value is taken which depends upon the diameters of the pair of wheels, and the number of teeth in the wheel for which the teeth are sought. This tabular value, when multiplied by the pitch, is to be found on the graduated edge A D B, Fig. 4, of the odontograph. This done, draw the tangent D E F to the pitch line at the middle point E of a tooth; and lay off the half thickness E D of tooth on either the tangent line or pitch line. Then place the graduated edge of the odontograph at D, and in such position that the number, and division of scale found as above, shall come precisely on the tangent line at D. Also get the curved edge, H F C, so that the curve will just lie tangent to the tangent line, as at F. Then all is ready for tracing the curve for the tooth face from the pitch line through D toward B as far as needed. By turning the instrument, which is graduated on both sides, over, and doing likewise, we get the opposite face of the same tooth. Then we have to simply draw the radial flanks when the tooth becomes fully delineated, with the exception of limiting the point and root. Clearance curves may also be struck in, if desired, as in

* These points follow from the fact that limited portions falling within a given angle at the pole are similar figures.

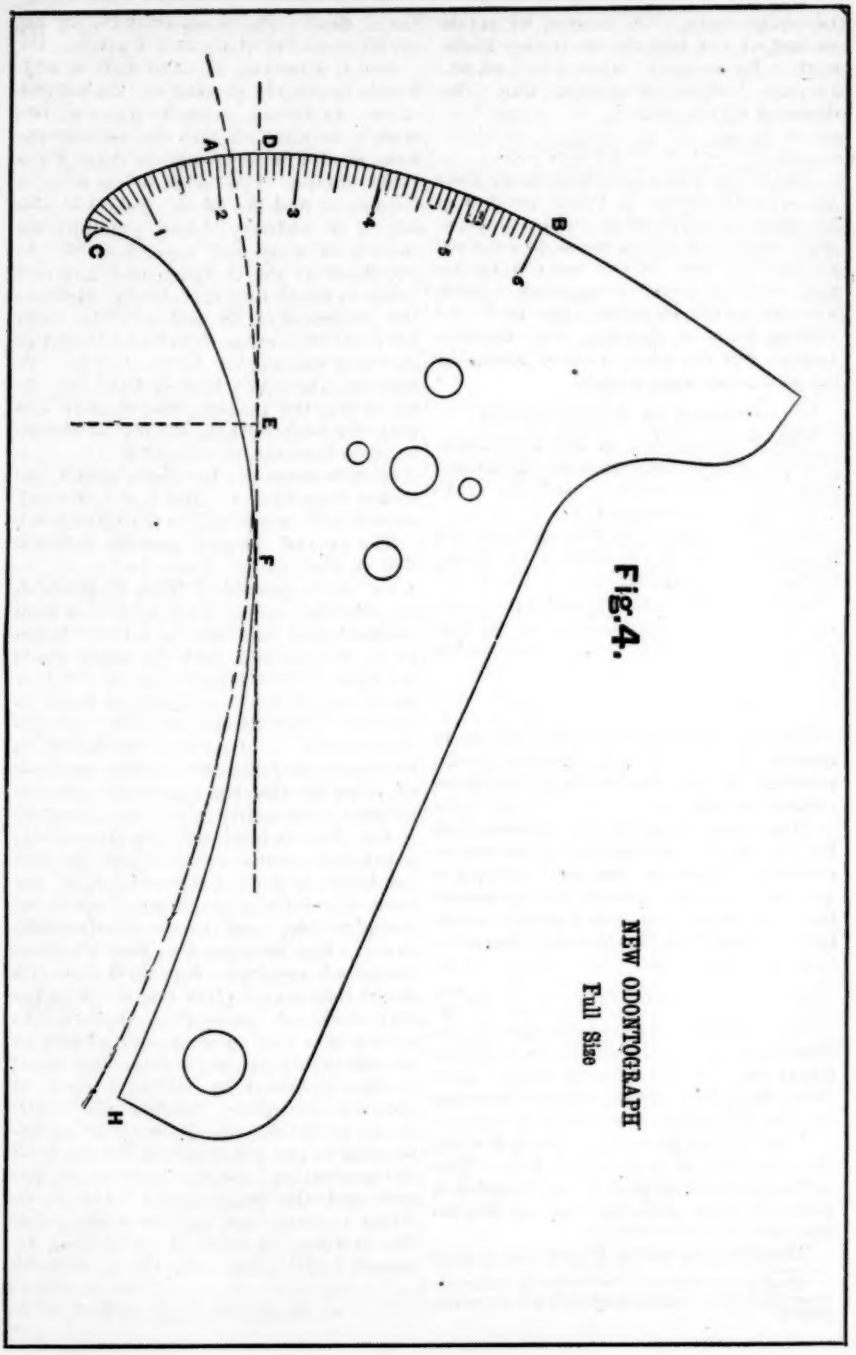


Fig. 4.

NEW ODONTOGRAPH
Full Size

any other case. Of course, when the setting of the instrument is once made, it may be mounted upon a rod, as, and for the purpose described above, for drawing all the teeth.

FOR INVOLUTE TEETH, ETC.

The curve which this instrument gives will closely represent initial portion of the hypocycloid, cycloid and involute, as well as the epicycloid, as far as required for a tooth face; and hence the instrument is adapted for tracing teeth of these various forms including the rack and pinion, internal gearing and involute teeth. For the latter form of teeth the tables become very simple.

CONDITIONS OF TOOTH CURVES.

Before proceeding to the demonstrations, it will be necessary to understand how the various curves, used for tooth outlines, are conditioned.

It is well known* that to generate the *epicycloidal faces for teeth with radial flanks*, the generating circles, which roll upon the pitch circles, should have diameters equal to the radii of the opposite pitch lines. That is to say: suppose the pitch circles and the generating circles to be in simultaneous rolling contact; the four circles having a single point of common tangency, with their four centers in a straight line. Then the generating circles will appear within pitch circles of twice their diameters, and the faces for each of the pitch circles will be described by the rolling circles which is in outside contact. Hence, as the odontograph is proposed to give nearly the epicycloid face for radial flanks, the above epicycloid is the one it should approximate to.

When one of the above circles is infinitely enlarged, we have the case of the *rack and pinion*, the epicycloid of the former being the cycloid generated by a circle half as large as the pinion; and its flanks are parallel to each other. Also the generating circle, whose diameter equals the radius of the rack, is infinite, and hence the generating circle for the pinion teeth is a straight line. This makes the faces of pinion teeth involutes, with the pitch circle the base of the involutes.

Therefore, for the rack and pinion with radial flanks, the faces of the rack are cycloids, and of the pinion involutes.

For the case of *involute teeth* for involute gearing in general, the base circles of the involutes are usually taken a little within the pitch circles; the ratio of the base circles being equal to that of the pitch circles. The relation between a base circle and the pitch circle containing it is arbitrary, being generally assumed, in each case, according to the judgment of the designer, and any rule given as regulating this simply expresses the judgment of its author. The table for involute teeth is therefore adapted to suit any assumption in this regard. In this case, however, it should be borne in mind that the tangent line, used in setting the odontograph, should be drawn to these base circles instead of the pitch circles, because the involutes are normal to the base circles. But the half pitch should still be laid off on the pitch lines.

The case of *internal gearing* is peculiar, in that radial flanks for the larger wheel are impossible.* That flank which approaches nearest to radial, is therefore adopted, and this can be readily shown to be the involute, with the pitch circle its base. Observing that the larger wheel has its flanks outside, and faces inside the pitch circle, we see that the flanks must be generated by rolling a curve on its exterior. Rolling a circle thus, we see that the epicycloid generated rises more nearly in a radial direction, as the circle is increased in size; because the latter curve reaches the greater height. Carrying this to the limit, we have the infinite generating circle or straight line, and hence the involute curve. But suppose we adopt a rolling circle of negative curvature, or one which incloses the pitch circle. Now for this mode of generation, it is easily shown that the curve generated will be an epicycloid exactly similar and equal to that obtained by rolling a circle of positive curvature, outside the pitch circle as before, the diameter of which is equal to the difference of diameters of the generating circle of negative curvature and the pitch circle. Hence, in either case, we get similar results, and the steepest epicycloid is the above named limiting one, viz., the involute.

* Willis, p. 103. Rankine, Machinery and Millworks, p. 133, &c., &c.

* See Belanger, Cinematique, p. 121.

The flanks of the larger wheel are therefore concave involutes. Using the same generatrix for the faces of the pinion, the latter will have involute faces.

The faces of the larger wheel will be hypocycloids, because internal, and generated by a circle whose diameter equals the radius of the pinion.

In *bevel wheels*, the pitch circles should be regarded as small circles of a sphere* which has its center situated at the point of intersection of the axes, or shafts of the wheels. These pitch circles are not, in the case of bevel wheels, the proper circles to lay out the teeth upon, but should be regarded as the bases of cones whose vertices are in the axes, outside the sphere, and which, developed upon a plane surface, are the desired circular arcs on which as pitch circles to delineate the teeth. The describing of teeth on these circles, being the same as on the pitch circles of spur wheels, the odontograph applies to them in the same manner, their radii number of teeth, &c., being employed in connection with the tables, instead of those of the real pitch circles.

In all these cases the same rule will apply for use of odontograph, except in involute gearing, with which we have an exception as above explained.

PARTICULAR LOGARITHMIC SPIRAL ADOPTED.

In adopting the particular logarithmic spiral for the odontograph curve, inasmuch as this curve may have an infinite variety of obliquities, it is evident that the selection is not a matter of indifference. When the obliquity, or angle between the normal and radius-vector, is very small, the arc of this spiral changes curvature less rapidly than when the obliquity is great: when the obliquity is zero, the spiral becomes a circle; and when it is 90°, the spiral is simply a radius; neither of which approximates to the epicycloid. To find that obliquity which makes the spiral best fit the epicycloid, it will probably be most satisfactory to assume an epicycloid which represents an average of those likely to be used for both curves, and adapt the spiral to it; though any ordinary logarithmic spiral will evidently conform more closely with it than the circle. The spiral which most closely osculates the epicycloid for a pair of equal pitch circles, is therefore adopted as the average spiral, because the opposite wheel may be made larger or smaller, thus making a higher or lower epicycloid. Also, it is preferable that the spiral fit for the fewest teeth, because for this the longest portion of the epicycloid would be required. The fewest number assumed is ten.

Let A F, Fig. 5, represent the pitch

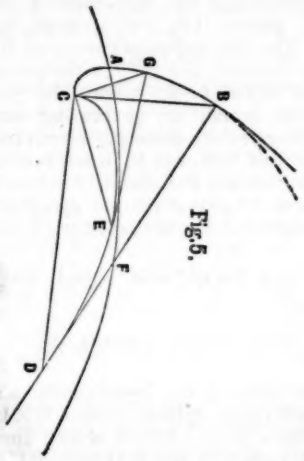


Fig. 5.

line, A B the epicycloid above named, dotted beyond B, and the full line CAB, the osculating logarithmic spiral with its pole at C. Draw normals G E and B D. These normals will be common to both the epicycloid and spiral, if they closely osculate each other at A and B. Also E D will be the evolute of both. The point B is supposed to be 0.3 pitch* above the pitch line, as the ordinary height of tooth above pitch line. Or, what is nearly the same, A B = 0.3 P. Also A G is assumed = 0.25 A B. Draw the normals or radii of curvature G E and B D. For the particular case under consideration we find for the epicycloid DE = 2 GB. This fact is most conveniently proved graphically on account of the compli-

* Willis, p. 146; Rankine, p. 144; Fairbairn, Mill and Millwork, part 2, p. 38. A. Lambert, Cinematique, Pl. 15.

* In all cases in this investigation, requiring dimensions to be given to the teeth, the common and well-known rule is adopted, viz.: Thickness of tooth, $\frac{4}{11}$ P. Thickness of space, $\frac{7}{11}$ P. Height above pitch line, $\frac{3}{10}$ P. Depth below, $\frac{4}{10}$ P. See Willis, p. 113, &c.

cation of the analysis. This solution was made with great care on a drawing, and it was also checked by an approximate analytical method. The results very nearly agreed, though as that by analysis was necessarily approximate, the graphical result was adopted. It happens to be also a very convenient figure. The graphical operation was, in fact, partly by analysis thus: The normal to the epicycloid always coincides with the chord of the generating circle connecting the point of contingence of this and the pitch circle with the tracing point. This determines the direction of G E or B D, where B F, for instance, is a chord. The true radius of curvature B D, for an epicycloid, is $\frac{4}{3}$ B F* in the present case for radial flanks where the pitch circles are equal, or generating circle half as large as the directing pitch circle. This value of B D or G E, in terms of the chord, is from the well-known formula for the radius of curvature for epicycloids in general,† and hence the length is computed.

Now the logarithmic spiral sought must have

$$\frac{ED}{BG}=2=\text{tangent of obliquity.}$$

The evolute of the logarithmic spiral, being an equal spiral,‡ makes C E D a spiral like C A B. Also it is well known that the radii C B and C D have B C D a right angle§ when these radii vectores are drawn to the extremities of a radius of curvature BB, and similarly for ECG. This, with the second property of constant obliquity of the logarithmic spiral, makes the two triangles B C D and G C E similar. From this it follows that the triangles C B G and C D E are similar, and hence

$$CB : BG :: CD : DE,$$

or

$$\frac{DE}{BG}=\frac{CD}{BC}=\text{tangent of obliquity}=2.$$

The equation of the logarithmic spiral is

$$\log. l=a\theta$$

in which a=tangent of obliquity, or $a=2$;

and therefore the logarithmic spiral sought has the equation

$$\log. l=2\theta$$

or

$$l=e^{2\theta}$$

or

$$\frac{l_1}{l_2}=e^{2(\theta_1-\theta_2)}.$$

Values of the radius vector, l, have been carefully computed for the purpose of laying out the odontograph curve with accuracy. These were computed for the intervening angles of $22\frac{1}{2}$ degrees, which divides the circumference into sixteen equal parts; and for some of the larger values the radii subdividing these angles as follows:

For $\theta_1-\theta_2=22\frac{1}{2}°$	$\frac{l_1}{l_2}$	= 2.1933
$\theta=\quad\theta_1$	l_1	= 0.5000
$"=\theta_1+22\frac{1}{2}°$	l_2	= 1.0966
$"=\theta_1+45°$	l_3	= 2.4052
$"=\theta_1+67\frac{1}{2}°$	l_4	= 5.2753
$"=\theta_1+90°$	l_5	=11.5700
$"=\theta_1+101\frac{1}{4}°$	$l_{5\frac{1}{2}}$	=17.1350
$"=\theta_1+112\frac{1}{2}°$	l_6	=25.3700
$"=\theta_1+123\frac{3}{4}°$	$l_{6\frac{1}{2}}$	=37.5820
$"=\theta_1+135°$	l_7	=55.6560

With these values, the odontograph, as shown in Fig. 4, was laid out, not only the curve A D B, but C F H; these being similar and equal as above explained. From the fact that tangent obliquity=2, we may, when a radius l is laid off for a point on A D B, draw a line at right angles, and lay off on it $2l$, which will give a point on C F.

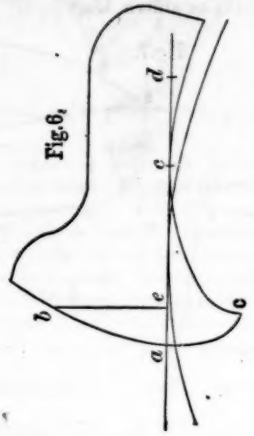
EQUATION OF THE ODONTOGRAPH CURVE.

In the analytical demonstration of the applicability of this curve, an equation will be needed for it, which can be combined with those for the curves which are proposed for the outlines of teeth. For reasons which will appear hereafter, an equation is required which gives the relation between the abscissas $a\,e$ and the ordinates $e\,b$, Fig. 6. Let $a\,c$ be the radius of curvature of the spiral at a. Let fall upon this a perpendicular $b\,e$. Also prolong $a\,c$ to d. Some point d can always be found with which, as a center, a circle may be struck through a and b. Now let us propose that $c\,d = q \times e\,b$ as a relation sufficiently exact for

* Davies and Pecks, Math. Dic., p. 222.
† See Rankine, Mach. and Millwork, p. 60, note. Redtenbacher Resultats, p. 3, rule 4. Willis, p. 142. Belanger, Cinematique, p. 108, &c.
‡ See Courtenay's Calculus, p. 181.
§ See Courtenay's Calculus, p. 173.

any possible height of tooth, $e\,b$, above pitch line.

Fig. 6.



Then we will have from the property of the circle,

$$a\,e\,(2\,a\,d - a\,e) = \overline{e\,b}^2,$$

or calling $a\,e = y$ and $e\,b = x$, $a\,c = \tau$, we have

$$y\,[2\,(\tau + q\,x) - y] = x^2$$

whence

$$\tau = \frac{x}{2}\left\{\frac{x}{y} + \frac{y}{x} - 2q\right\} \quad . \quad . \quad (1)$$

If, in this equation, q proves to be constant, we have the equation desired. To this end the following results have been very carefully determined graphically, this method being the only one admissible for complexity of formulas:

For $\tau = 2.0$ inch	$x = 1.1$ inch	$q = .596$
$\tau = 2.0$ inch	$x = 2.0$ inch	$q = .588$
$\tau = 4.4$ inch	$x = 1.0$ inch	$q = .561$
$\tau = 4.4$ inch	$x = 2.5$ inch	$q = .557$
$\tau = 4.4$ inch	$x = 4.5$ inch	$q = .562$
$\tau = 9.0$ inch	$x = 0.5$ inch	$q = .595$
$\tau = 9.0$ inch	$x = 9.0$ inch	$q = .599$
$\tau = 9.5$ inch	$x = 2.2$ inch	$q = .555$
$\tau = 9.5$ inch	$x = 5.5$ inch	$q = .600$
Mean . .		$q = .579$

These figures show that q is very nearly constant; in fact, the differences can only be accounted for as errors of the graphical operation; errors which might be expected for the reason that the point d, Fig. 6, may vary its position considerably, and yet cause but slight variations at b. We may therefore adopt this, not only as constant, but as the correct value of q for the particular spiral chosen, and this value was employed in the formulas when computing the tables for the odontograph.

DEMONSTRATION FOR EPICYCLOIDAL SPUR GEARING.

To show that the odontograph, as above proposed, is applicable to the case of ordinary epicycloidal gearing-teeth with radial flanks, it will be necessary to prove that the value of τ to be found on the scale by which the instrument is set, can be computed when certain functional parts of the gears in question are known; and also, to show that it can be expressed in so few terms, that values of it may be computed beforehand, and arranged in tabular form, it will be necessary to resort to mathematical expressions for τ, by which it can be discussed, and by which we may determine the number of quantities required to express it. For instance, if it can be expressed in terms of two different quantities only, one table will suffice for all values of τ. But if it requires three quantities for its expression, a series of tables will be necessary.

By aid of the equations of the epicycloid the above co-ordinates x and y may be expressed in quantities belonging to the wheels.

Let R = the radius of the pitch circle of the wheel for which the teeth are sought, whether it be the larger or smaller.

Let N = the number of its teeth.

Let r = the radius of the wheel which is to work with the wheel sought, and equal to the diameter of the rolling circle for generating the faces sought.

Let n = the number of its teeth.

Let P = the pitch of the teeth $= \frac{2\,\pi\,R}{N} = \frac{2\,\pi\,r}{n}$.

Let τ = the radius of curvature of the curve of odontograph, as above, the numerical value of which is also the number to be used for setting the instrument, also the tabular numbers.

Let x and y=co-ordinates as in equation (1) of odontograph curve above, x=0.3 P.

Let θ=an angle, which may be considered as an auxiliary quantity, simply; or as the angle which locates the center of the rolling circle.

Then the well-known * polar equation of the epicycloid is—

$$(\text{rad.vector})^2=(R+x)^2=R^2+r\left\{R+\frac{r}{2}\right\}\left\{1-\cos.\frac{2R}{r}\theta\right\}$$

whence

$$\cos.\frac{2R}{r}\theta=1-\frac{\left\{1+\frac{x}{R}\right\}^2-1}{\frac{r}{R}\left\{1+\frac{r}{2R}\right\}}$$

or

$$\cos.\frac{2N}{n}\theta=1-\frac{\left\{1+\frac{0.3\,P}{R}\right\}^2-1}{\frac{n}{N}\left\{1+\frac{n}{2N}\right\}} \quad (2)$$

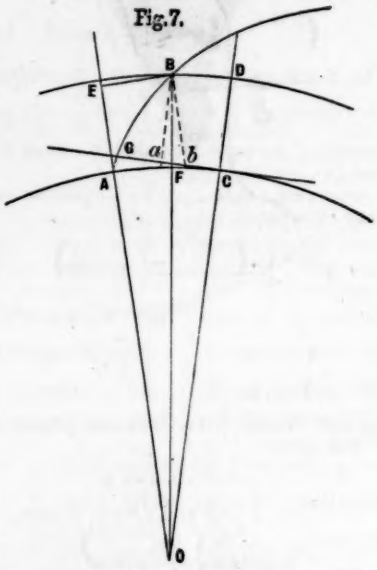
This value of θ is in terms of the two quantities $\frac{P}{R}$ and $\frac{n}{N}$ only, as desired.

The polar equation is here employed instead of that referred to rectangular co-ordinates, because the former is resolvable with respect to θ, and the latter not. The latter, however, would have been preferable to the extent of about the difference between the height of b, Fig. 6, above the tangent and above the pitch line, because $b\,e$, which is about midway between a, and the middle of the tooth, is almost exactly equal to x as given by the rectangular equation. But this difference is very small in wheels of the fewest teeth, say 8 or 10, and inappreciable in larger wheels.

An expression for y is most readily obtained by employing the well-known † equation of y in terms of θ for rectangular co-ordinates to the epicycloid.

In Fig. 7, let A B represent the face of the tooth for the wheel whose center is O. Take C D the height of the tooth above the pitch line reckoned on the center line of tooth, and = B F = 0.3 nearly = x. Let C G represent the tangent to the pitch line at the center point C of tooth, as above described.

Fig. 7.



Now, since the co-ordinates x and y in equation (1) of the odontograph curve represent the height of B above the tangent C G, and the distance from the face along the tangent C G to the perpendicular let fall from B upon C G respectively, or equal to B F and A a respectively, very nearly, we have to find, by help of the equation of the epicycloid, between y and θ, the value of A a. But this equation gives E B, = A b. Drawing B b parallel to A E, and B a parallel to D C, we have

$$a\,b : F\,B :: A\,C : C\,O$$

or

$$a\,b : x :: \tfrac{5}{11}\,P : R$$

since the thickness of tooth=$\frac{5}{11}$ P.

Hence

$$a\,b=\frac{5}{22}\,\frac{x\,P}{R}=\frac{0.3\,P^2}{R}=\frac{P^2}{R}0.06819$$

and hence, by aid of the equation of the epicycloid,

$$A\,a=y=E\,B-a\,b=\left(R+\frac{r}{2}\right)\sin.\,\theta-\frac{r}{2}\sin.\left(\frac{2N}{n}+1\right)\theta-a\,b$$

* See Price's Calculus, vol. i, p. 349.

† See Price's Calculus, vol. i, p. 283.

or

$$\frac{y}{P}=\frac{R}{2P}\frac{n}{N}\left\{\left(\frac{2N}{n}+1\right)\sin.\theta-\sin.\left(\frac{2N}{n}+1\right)\theta\right\}-\frac{P}{R}0.06819 \quad (3)$$

This equation, together with (2), enables us to compute $\frac{y}{P}$ when $\frac{P}{R}$ and $\frac{n}{N}$ only are known, θ being eliminated between (2) and (3).

Observing that $x=0.3$ P, equation (1) may be written

$$\frac{\tau}{P}=0.15\left(\frac{.3P}{y}+\frac{y}{0.3P}-2q\right) \quad . \quad (4)$$

So that $\frac{\tau}{P}$ becomes fully known when the two quantities $\frac{P}{R}$ and $\frac{n}{N}$ belonging to the pair of wheels under consideration become known. Or, observing that $\frac{P}{R}=\frac{2\pi}{N}$, the most convenient forms of the equations for computation are

$$\cos.\frac{2N}{n}\theta=1-\frac{\left(1+\frac{1.885}{N}\right)^2-1}{\frac{n}{N}\left(1+\frac{n}{2N}\right)}. \quad (5)$$

$$\frac{y}{P}=0.07958\,N\frac{n}{N}\left\{\left(\frac{2N}{n}+1\right)\sin.\theta-\sin.\left(\frac{2N}{n}+1\right)\theta\right\}-\frac{0.42841}{N}. \quad . \quad (6)$$

$$\frac{\tau}{P}=0.15\left(\frac{0.3P}{y}+\frac{y}{0.3P}-1.158\right) \quad . \quad (7)$$

These formulas enable us to compute $\frac{\tau}{P}$ when $\frac{N}{n}$ and N are known. Table I contains most of the values $\frac{\tau}{P}$ needed in practice, and obtained from these formulas. The tabular value of $\frac{\tau}{P}$, when multiplied by P gives τ the index number for setting the odontograph. Examples will be given hereafter, illustrating the use of the instrument and table in delineating gear teeth.

DEMONSTRATION FOR THE RACK AND PINION.

For this case formula (6) becomes indeterminate, and hence fails. It will, therefore, be necessary to deduce others.

The cycloid for the tooth faces on the rack, flanks radial, will have the following values of x and y*:

$$x=\frac{r}{2}\left(1-\cos.\theta\right)$$

$$y=\frac{r}{2}\left(\theta-\sin.\theta\right)$$

and hence

$$\cos.\theta=1-\frac{1.2\pi}{n} \quad . \quad . \quad . \quad (8)$$

$$\frac{y}{\tau}=\frac{n}{4\pi}\left(\theta-\sin.\theta\right) \quad . \quad (9)$$

By expanding cos. θ into a series and dropping all after θ^3, by which we involve an error of only $\frac{1}{75}$ part for the case of 8 teeth, and much less for a greater number; and similarly expanding sin. θ into a series, omitting the terms following θ^3 with an opposite error of $\frac{1}{50}$ for 8 teeth, giving a residual error of about $\frac{1}{50}$ we may write,

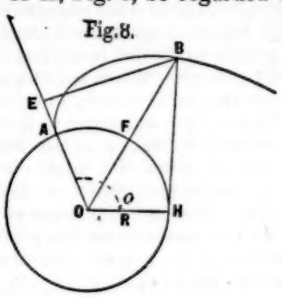
$$\frac{y}{P}=\frac{1}{10}\sqrt{\frac{2.4\pi}{n}} \quad . \quad . \quad (10)$$

This, combined with (7), was used for computing the tabular values for racks given at the bottom of table I.

For the involute faces of the pinion we readily obtain special formulas.

Let A H, Fig. 8, be regarded as the

Fig. 8.



pitch line, AB as a tooth face of the involute form, and B F height of tooth above the pitch line and equal to $0.3\,P = x$. We will have $a\,b$ same as before.

$$\therefore \quad y=EB-a\,b$$

as in Fig. 8.

$$EB=(R+BF) \text{ arc } BOE \text{ nearly}$$

$$=(R+0.3\,P)\,(\theta-BOH)$$

$$HB=AFH=R\,\theta=R \text{ tang. } BOH$$

* Price's Calculus, vol. i, p. 280.

Hence

$$y = \text{E B} - a\,b = (\text{R} + 0.3\ \text{P})\ (\theta - \text{tang.}^{-1}\theta) - a\,b$$

or

$$\frac{y}{\text{P}} = \left(\frac{\text{N}}{2\pi} + 0.3\right)\left(\theta - \text{tang.}^{-1}\theta\right) - \frac{0.42841}{\text{N}} \quad . \quad (11)$$

and

$$\overline{\text{B H}}^2 = \overline{\text{R}\,\theta}^2 = (\text{R} + 0.3\ \text{P})^2 - \text{R}^2$$

or

$$\theta^2 = \left(1 - \frac{0.6\,\pi}{\text{N}}\right)^2 - 1 \quad . \quad (12)$$

which equations, combined with (7), were used in bringing out the tabular quantities marked "Pinion" near the bottom of table I.

It is observed that we have one line of values only for each, the rack and pinion, the reason for this is that the value of $\frac{r}{\text{P}}$ for the rack and pinion become known in terms of one arbitrary quantity instead of two.

DEMONSTRATION FOR WHEELS WITH INVOLUTE TEETH.

Having a set of values of $\frac{r}{\text{P}}$ for involute faces, we are at once prepared to lay out any involute gear-teeth with the odontograph, from the fact that in this form of teeth each wheel is independent of all others. In this case, however, we must observe that the tangent line E D, Fig. 4, should be drawn to the base circle instead of from the pitch circle, as stated above under *conditions* for involute teeth. The half thickness of tooth should still be laid off on the pitch line, because this is the proper line to reckon tooth thicknesses on.

DEMONSTRATION FOR WHEELS IN INTERNAL GEAR.

First consider the larger wheel, in which the faces are internal and hence hypocycloids. Equations (2) and (3) apply to this case by changing the sizes of r and x, and hence

$$\cos.\frac{2\,\text{R}}{r}\theta = 1 - \frac{1 - \left(1 - \frac{x}{\text{R}}\right)^2}{\frac{r}{\text{R}}\left(1 - \frac{r}{2\,\text{R}}\right)}$$

or

$$\cos.\frac{2\,\text{N}}{n}\theta = 1 - \frac{1 - \left(1 - \frac{0.6\,\pi}{\text{N}}\right)^2}{\frac{n}{\text{N}}\left(1 - \frac{n}{2\,\text{N}}\right)} \quad (13)$$

and

$$\frac{y}{\text{P}} = \frac{\text{R}}{2\,\text{P}}\,\frac{n}{\text{N}}\left\{\left(\frac{2\,\text{N}}{n} - 1\right)\sin.\theta - \sin.\left(\frac{2\,\text{N}}{n} - 1\right)\theta\right\} + \frac{0.6\,\pi}{\text{N}}\,0.2273 \quad (14)$$

which, combined with (7), were used in producing the first part of table II. The flanks of the pinion are supposed to be radial, and those of the wheel involutes as set forth under *conditions* for these wheels. The external involute flanks of the wheel are laid out by aid of the values given in table I for "*pinion*," the tangent line E D, Fig. 4, being drawn to the pitch line from the middle of a *space*, to suit the present reversed conditions from outside to inside.

The faces of the pinion, being also *involutes*, the same set of tabular values last-named apply.

CASE OF BEVEL WHEELS.

Observing the explanations above noted regarding bevel wheels, either epicycloidal or involute teeth may be laid out for these wheels.

EXAMPLES.

To show the application of the above tables, the following examples are given; Let the pair of wheels be the same for each example, the teeth simply being different; let the number of teeth in the smaller wheel be 16 and in the larger 56. Also take the same pitch for all, and equal to two inches.

1st. For *epicycloidal teeth* with radial flanks. For this we must use table I, which requires the ratio of the radii of the wheels; or, what is the same thing, the ratio of the number of teeth in the wheels.

For the larger wheel we have

$$\frac{\text{R}}{r} = 3\tfrac{1}{2} \text{ and } \text{N} = 56.$$

At the top line of the table we find the number "56" corresponding to N. Following the column down we see that the ratio of the radii comes midway between .473 and .409. Taking the mean

TABLE I.

FOR EPICYCLOID TEETH WITH RADIAL FLANKS.

Values of $\frac{\tau}{P}$ *in inches:* or, number by which to multiply the pitch, measured in *inches*, to obtain the index number for setting the odontograph.

$\frac{R}{r}$ or $\frac{r}{R}$ Radius of wheel sought. / Radius of other wheel.	Number of teeth in wheel for which the teeth are sought, N and n.												
	8	16	24	32	40	48	56	64	72	80	88	96	112
$\frac{1}{12}$=.083	.321	.458	.555										
$\frac{1}{6}$=.167	.317	.450	.551	.634	.704								
$\frac{1}{4}$=.250	.311	.438	.540	.624	.692	.780	.856						
$\frac{1}{3}$=.333	.300	.426	.526	.611	.679	.770	.831	.869	.910	.965	1.017	1.080	1.225
$\frac{5}{12}$=.417	.293	.417	.515	.598	.666	.741	.808	.853	.894	.948	1.000	1.052	1.147
$\frac{1}{2}$=.500	.283	.406	.504	.584	.654	.722	.786	.834	.878	.930	.980	1.032	1.132
$\frac{7}{12}$=.583	.272	.394	.492	.573	.640	.705	.766	.817	.862	.911	.960	.995	1.107
$\frac{2}{3}$=.667	.266	.382	.479	.558	.627	.690	.748	.799	.845	.895	.946	.987	1.089
$\frac{3}{4}$=.750	.252	.369	.467	.545	.613	.677	.733	.784	.834	.878	.923	.973	1.066
$\frac{5}{6}$=.833	.245	.379	.456	.534	.602	.662	.721	.768	.820	.862	.905	.957	1.047
$\frac{11}{12}$=.917	.238	.348	.446	.522	.590	.648	.709	.754	.806	.847	.892	.938	1.037
1.	.230	.338	.435	.510	.577	.634	.693	.740	.791	.832	.876	.919	1.007
$\frac{11}{12}$=1.09	.221	.329	.423	.500	.563	.621	.679	.722	.774	.813	.856	.898	.990
$\frac{6}{5}$=1.20	.211	.318	.411	.489	.548	.607	.661	.705	.755	.794	.836	.877	.968
$\frac{4}{3}$=1.33	.202	.307	.396	.472	.532	.590	.640	.685	.731	.771	.812	.855	.935
$\frac{3}{2}$=1.50	.193	.294	.381	.452	.511	.571	.618	.663	.707	.727	.789	.827	.896
$\frac{12}{7}$=1.71	.183	.278	.362	.428	.487	.542	.591	.636	.678	.716	.756	.794	.848
2	.174	.260	.336	.400	.458	.511	.560	.604	.642	.679	.715	.748	.795
$\frac{12}{5}$=2.40		.219	.304	.362	.421	.474	.523	.562	.597	.633	.663	.693	.739
3			.265	.321	.379	.428	.473	.508	.540	.572	.600	.624	.673
4				.271	.328	.374	.409	.435	.467	491	.521	.548	.600
6					.254	.289	.321	.348	.372	.397	.428	.460	.519
12								.257	.292	.286	.318	.361	.417

For both Rack and Pinion, use number of teeth in *pinion* for N, above.

Rack...	.338	.513	.657	.777	.884	.982	1.071	1.155	1.233	1.304	1.378	1.444	1.573
Pinion..	.323	.443	.551	.642	.718	.785	.847	.897	.941	.990	1.032	1.067	1.122

TABLE II.

FOR INVOLUTE TEETH.

Values of $\frac{\tau}{P}$ *in inches:* or, number by which to multiply the pitch, measured in inches, to obtain the index number for setting the odontograph.

Number of teeth in wheel: or N and n.

8	16	24	32	40	48	56	64	72	80	88	96	112
.323	.443	.551	.642	.718	.785	.847	.897	.941	.990	1.032	1.067	1.122

N. B.—The tangent should be drawn to the base circles.

for the interpolated value, we have .441 as the multiplier for the pitch. Hence

$$.441 \times 2 \text{ inches pitch} = .882 \text{ inches},$$

which is the index number, or the number to look out on the scale A D B, Fig. 4, which point must be brought to coincide with the tangent D E. Then, placing the curve C F tangent to the tangent line as shown in the figure, the tooth face curve may be drawn.

For the smaller wheel we have

$$\frac{r}{R} = .286+, \text{ and } n = 16.$$

Running down the column headed "16," we find no ratio = .286, but .250 and .333. Interpolating by the well-known method of proportional parts, we find for the multiplier the number .433. Hence

$$.433 \times 2 = .866 \text{ inches}.$$

which is the setting or index number required for the small wheel.

2d. For the *rack*, suppose the large wheel is made infinite and the pitch line straight. Then the pinion will have 16 teeth, and the multiplier is .513. Hence

$$.513 \times 2 = 1.023 \text{ inches},$$

which is the index number for setting the odontograph to the straight line of the rack.

For the *pinion*, we find the multiplier to be .443. Hence

$$.443 \times 2 = .886 \text{ inches},$$

which is the required number for the pinion.

3d. For the case of *involute teeth*, the multiplier for the larger wheel is .847, table II, and for the smaller it is .443.

4th. For the case of internal gearing we have, for obtaining the external involute flanks,

$$\frac{R}{r} = 3\tfrac{1}{2}, \text{ and } N = 56.$$

Not finding 56 in the line of numbers of teeth, table III, we interpolate between 40 and 60 for the ratio 3. This gives for N = 56 the multiplier .649. Similarly for ratio 4, we find multiplier .490. Taking the mean of these for the ratio $3\frac{1}{2}$, and we get .569 as the desired multiplier. Hence

$$.569 \times 2 \text{ inches pitch} = 1.138 \text{ inches}.$$

for the index number.

For the faces of the wheel we find, from the lower line of table III, .841 as

Table III.

For internal gearing, pinion flanks radial.

Values of $\frac{r}{P}$ *in inches:* or, number by which to multiply the pitch, measured in inches, to obtain the index number for setting the odontograph.

$\frac{R}{r}$ or Radius of wheel. / Radius of pinion.	Wheel: Number of teeth, or N.						
	8	16	24	40	60	100	150
2	*Faces*	.400	.556	.818	1.082	1.514	1.887
3		.210	.317	.497	.687	1.017	1.322
4			.232	.370	.520	.767	1.027
6				.268	.387	.555	.687
12					.282	.387	.447
	Flanks of wheel and *faces* of pinion.						
	.323	.443	.551	.718	.872	1.084	1.270

N. B.—In laying out the *flanks* for the *wheel*, the tangent should be drawn from the center of the space, and not center of tooth.

the required multiplier, and 1.682 as the index number.

To set the odontograph. Observing the foot-note of table III, the tangent line E D, Fig. 4, to which the instrument is set, is drawn from the middle of the space, as though the space in this case, outside the pitch line, were a tooth.

For the faces of the pinion teeth the multiplier is .443, as in lower line of table III, &c., &c.

MODIFIED FORM OF THE WILLIS ODONTOGRAPH.

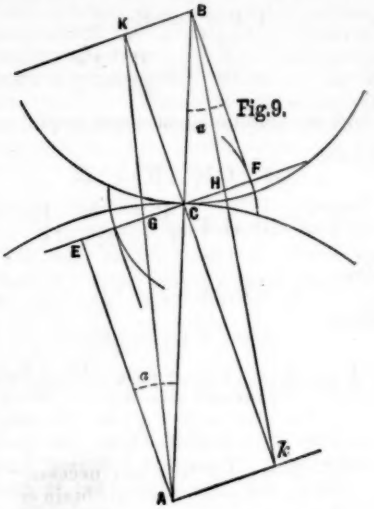
The odontograph now under consideration is termed a modified form of the Willis odontograph, not because it bears any resemblance to the Willis odontograph, but because it is based upon the theory of Prof. Willis for the forming of teeth of wheels by circle arcs, and also because it gives centers to tooth arcs as does the Willis odontograph, instead of forming in itself a template for the curves.

By constructing the instrument so that it can be set to various angles, instead of being fixed at 75°; and by preparing suitable tables to accompany it, we may be able with it to lay out teeth with straight flanks for all wheels, the faces of the teeth being circular arcs whose centers are given by the instrument.

The analysis by which these facts are demonstrated is essentially that of Prof. Willis, and given in his *Principles of Mechanism*, 2d ed., pp. 132, 136.

According to the Willis theory for forming each tooth with four circular arcs, whose centers are on the line of action, if certain centers be removed to an infinite distance, the arcs struck from such centers will be straight lines, perpendicular to the line of action. This is supposed to be done in the present case for the flank arcs, and when the line of action is suitably inclined, these perpendiculars become radii on the pinion and inclined lines on the wheel.

With these conditions imposed at the outset, the analysis becomes extremely simple, as follows: In Fig. 9 let A and B represent the pitch circles, C the pitch point, and E F the line of action. Draw A E and B F perpendicular to E F as shown. Let α = angle C A E = C B F, A C = R, B C = r, and C G = D. Now Prof. Willis' diagram, p. 135, becomes Fig. 9 when A k and B K are made parallel to line of action as in Fig. 9. I will simply explain Fig. 9, referring



those who wish to study the diagram further to Prof. Willis' book. G is a center for describing a tooth face of A, and H a center for a face of a tooth of B. The center for the flank against which the face, struck from G, works, being on B K at an infinite distance, the flank is perpendicular to E F. The point serving as the origin for this face and flank may be assumed at any position * on the line E F, but should generally be not far from F, and for radial flanks for B, must be at F. Similarly for E if the flanks for E are to be radial.

To render the odontograph convenient in practical use, and to keep the radii of the tooth faces within reasonable limits for all cases, such as when the pair of wheels are of equal size and also of very different sizes, it is found advisable to make the flanks of the smaller of the pair of wheels or pinion radial in all cases; and for the larger wheel, of such inclination that the same radius for the tooth faces of the wheel will be right for the pinion. To this end C F is taken, arbitrarily equal to one-third of the pitch, so that the radius of the faces for

* This fact is pointed out by Prof. Willis.

both wheels is $G F = G C + \frac{1}{3}$ pitch. The point G is given by the odontograph and it is easy to lay off a third of the pitch C F. Then we will have, C F B being always preserved a right angle,

$$C F = \frac{P}{3} = r \sin. \propto$$

$$\therefore \sin. \propto = \frac{P}{3\,r} = \frac{2\,\pi}{3\,n}$$

where n = number of teeth in pinion.

Again

$$C F : C H :: R + r : R$$

$$C H = D = C F \frac{R}{R+r} = \frac{R}{R+r} \cdot \frac{P}{3}$$

But

$$C F : C E :: r : R$$

and

$$C G : C E :: r : R + r$$

$$\therefore C G = C E \frac{r}{R+r} = C F \frac{r}{R+r} \frac{R}{r} = \frac{R}{R+r} \frac{P}{3}$$

or

$$C G = C H.$$

This shows that it is only necessary to set the odontograph once to obtain either C G or C H. Taking the distance from C to the origin of tooth arcs the same for both wheels gives equal radii for the faces of both wheels, and the arcs and flanks are easily struck in as shown in Fig. 9. To draw all other arcs the centers may be found, which lie in circles concentric with the pitch lines. The drawing of the non-radial flanks of A will require a little attention that they be drawn at the proper angle with the radius, or rather simply perpendicular to E F at the proper point.

The quantities $\propto$ and $\frac{D}{P}$ are given in terms of n and $\frac{R}{r}$, respectively, in the following table for a number of values, which will aid in the practical use of the instrument, the necessary setting values being thus obtained beforehand. When the data fall between values in the table, interpolations will be necessary, though readily made.

THE INSTRUMENT, AND MODE OF USING IT.

The modified odontograph is shown full size in Fig. 10, with its scales, &c., ready for use, in delineating teeth of six inches pitch.

TABLE IV.

FOR THE MODIFIED WILLIS ODONTOGRAPH.

Values of the setting angle $\propto$, *and of* $\frac{D}{P}$ *for position of arc center*, for tooth face for radial flanks for *pinion* and for inclined flanks for the wheel.

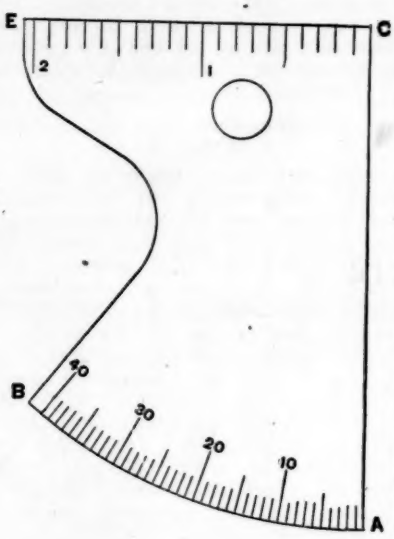
Number of teeth in pinion, $=n$.	Setting angle for odontograph, $=\propto$	Larger radius divided by smaller, $=\frac{R}{r}$	Tooth center distance divided by pitch, $=\frac{D}{P}$
	Deg. Min.		
10	12 05	1	.167
15	8 02	1.5	.200
20	6 01	2	.222
30	4 00	3	.250
40	3 00	4	.267
60	2 00	5	.278
80	1 30	6	.286
100	1 12	7	.292
130	0 55	8	.296
160	0 45	9	.300
200	0 36	10	.303
260	0 28	11	.306
300	0 24	12	.308

N. B.—The two parts of this table are entirely independent of each other, the first giving the setting angle $\propto$, without regard to where the line is in second part of table giving $\frac{D}{P}$.

In using the instrument the point C is to be brought to the pitch point C, Fig. 9. Then the angle $\propto$ obtained from the table is to be looked out on the sectoral scale A B, and that point placed upon the radius A C, Fig. 9. The instrument is then in position. A line should then be drawn along E C and produced in the direction of F, perpendicular to which the flanks are to be drawn. Then the distance D, obtained by multiplying $\frac{D}{P}$ of the last table by P, is to be set off on the scale C E, Fig. 10, which point is the center G, Fig. 9, from which to strike the tooth face. Then C F, equal $\frac{1}{3}$ P as explained above, is set off on line E F as the origin of a tooth face and flank as shown in Fig. 9. We then have the length G F for the radius of a face of A, which is also the radius for the faces of B to be used at the center H. The flanks are perpendicular to E F and tangent to the tooth arcs as shown,

and each face works with its tangent flank, as shown in Fig. 9. By repeating these faces and flanks the teeth become fully drawn, as in Fig. 13. The flanks of the smaller wheel are always radial,

Fig. 10.



MODIFIED WILLIS ODONTOGRAPH

but those of the larger wheel never, except in case both wheels become equal, when the flanks of both are radial.

It will hardly be necessary to follow this description with an example.

ODONTOGRAPH TEETH COMPARED.

Fig. 11 is an accurate drawing of a part of the teeth of a pair of wheels as laid out by the well known *Willis Odontograph.*

Fig. 12 is likewise a carefully executed drawing of a portion of the same pair of gears as laid out by the *New Odontograph.*

Fig. 13 shows the form of teeth of the same pair of wheels as laid out by the *Modified Willis Instrument.*

The smaller of the wheels has twelve teeth, and the larger has 144 teeth.

These drawings will enable the reader to form a very correct opinion as to the relative merits of the results of the three instruments. This is not difficult to such as are familiar with the proper form of gear teeth. While this may be true, still it remains doubtful which to adopt for practical use. Such doubts however may be removed on taking a direct comparative view of the respective difficulties, and conveniences of application of the three instruments, which, for the purpose of furthering this object is given below.

PRACTICE WITH THE THREE ODONTOGRAPHS COMPARED.

The well known *Willis Odontograph*, in laying out one side of a tooth requires: 1st, that the pitch be laid off on the pitch line; 2d, that this pitch be bisected to obtain the origin of arcs; 3d, that a radius be drawn at one end of the pitch and the instrument placed on it; 4th, a quantity taken from a table by which the center point is found on the odontograph scale and point noted on drawing; 5th, that the instrument be then placed on the other radial line; 6th, a second quantity taken from the table by which a second center point is found and noted on drawing for a second arc center; 7th, that a pair of dividers be placed at one center, the face or flank struck; 8th, that similarly a flank or face be struck from the second center; 9th, and finally that caution be exercised to point off the right center at the two settings of instrument, and also that the proper part, flank or face, be drawn from the centers.

The *New Odontograph* in laying out the side of a tooth requires: 1st, that a tangent line be drawn to the pitch circle; 2d, that the half thickness of tooth be laid off from the point of tangency; 3d, a quantity looked out from a table; 4th, that this be multiplied by the pitch by which the instrument is properly set on the tangent line; 5th, that a scribe be drawn along edge of instrument for the *face;* 6th, and lastly, that a radial flank be drawn from the intersection of face with the pitch line.

The *Modified Willis Odontograph* requires: 1st, that a radius be drawn; 2d, that a setting angle be found from a table by which the instrument is set;

Fig.11.

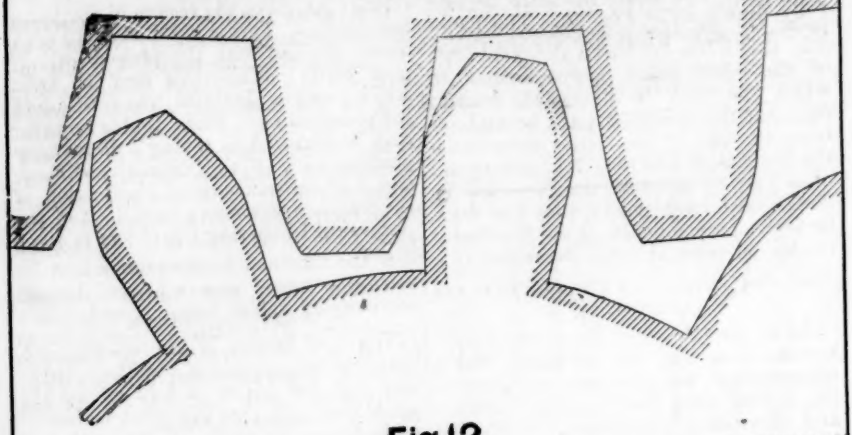


Fig.12.

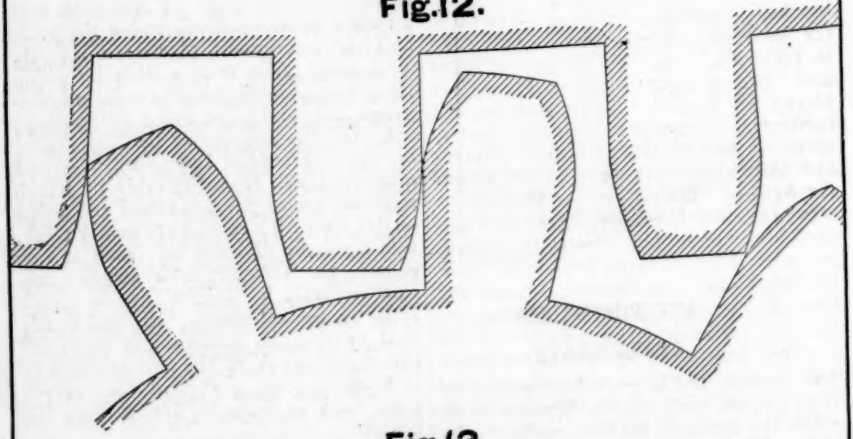
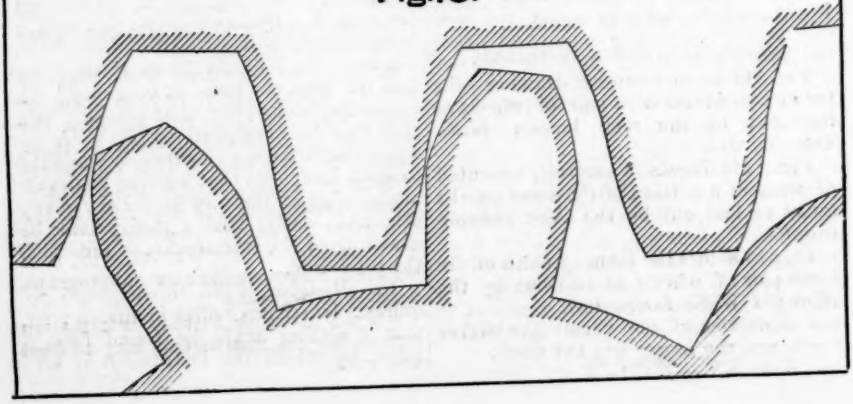


Fig.13.



3d, that a second quantity be taken from a table; 4th, that this quantity be multiplied by the pitch, by which the center point for the face is found and noted; 5th, that a line be drawn along the edge of the odontograph, perpendicular to which the flank is afterwards drawn; 6th, that the one-third pitch be laid off from the end of the radius upon which the instrument was set; 7th, that by aid of a pair of dividers the face arc be struck; 8th, and finally, that the flank be drawn perpendicular to the line traced for the purpose, as above described.

COMPARATIVE VIEW OF THE INSTRUMENTS AND TABLES.

As to the tables for the three instruments, those for the modified Willis odontograph are the most compact of all, having only four vertical columns and fourteen horizontal, or fifty-six blocks, including everything. The table for the Willis odontograph, as published in his book,* has nine vertical columns and twenty-eight horizontal, or 250 blocks for figures. As printed on the card which accompanies the brass instrument, it has fourteen vertical columns and thirty horizontal ones, or 420 blocks for figures. The tables for the new instrument, that for radial flanks and epicycloidal teeth, has fourteen vertical columns and twenty-six horizontal ones, or 304 blocks for figures; or, adding those for table for internal gearing, we get 353. It is believed also, that table I might be reduced by cutting out about half of the horizontal columns, and still the gaps to be filled, in practice, by interpolation be no greater than in the tables for the Willis instrument. This would reduce the tables for the new odontograph, for epicycloidal and internal gearing to 210 blocks for figures. Then adding the seventy-three blocks for figures in tables II and III, we have the tables for applying the new instrument to all ordinary forms of gears occupying 283 blocks for figures, a number of places much less than is found in the tables on the printed card accompanying the Willis instrument, and but few more than given in the tables published in Professor Willis' book. Taking the table that accompanies the instrument, as the one which it is fair to compare with, we find the tables for the new instrument most compact.

Comparing the instruments themselves for compactness, we see, by reference to the figures, that the modified Willis instrument is a little ahead, though either this, or the new one, may be carried under the tuck of a common pocket-book. In this regard, either of the new instruments possess a degree of portability and ready usefulness, not common to an instrument 6×14 inches, as in the older form of odontograph. In fact the new and modified instruments might be treated as mere "pocket pieces," the accompanying tables being recorded in a note-book. This matter of compactness of tables and instruments is, however, only of secondary importance when *counterposed* with desirable results and facility of obtaining them.

These comparisons indicate that the modified Willis odontograph has advantages in the minor points of compactness of instrument and tables. But in the more essential qualities of simplicity of application, the new instrument, as above pointed out, appears to be superior in the ratio of six to eight or nine; and of form of tooth, superior in the almost mathematical correctness of the curves for faces, and in having radial flanks, as indicated by Figs. 1, 2, 11, 12, and 13. Designers of gearing, familiar with properly formed gear teeth, however much they may admire the short-cuts secured by odontographs, will undoubtedly deprecate the angularity of junction of flanks and faces found in the Willis tooth, and the rude approximation to correct tooth curves inseparable from the circle arc. The excessively thick base of tooth found in Fig. 1, 11, and 13 are undesirable features.

Fig. 12, as compared with Figs. 11 and 13, shows superiority in form of tooth, which, by those who advocate the common form of radial flanks at least, cannot be questioned. This superiority of form of tooth, added to the compactness of instrument and especially to the important advantage possessed by it of great facility of application, will, it is believed, merit for the new odontograph decided preferences.

Parties desiring further information concerning the instruments may address the writer.

* Willis, p. 137.

SPRING PROPULSION FOR STREET CARS.

By EDWARD H. LEVEAUX.

From "Journal of the Society of Arts."

Some years back I was struck with the simplicity of the ordinary toy mouse, which by a few turns of a common watch key in the hands of pater-familias gives so much pleasure to the younger members of his family; and it appeared to me, with an improved method of spring coiling and tempering, a carriage for passengers might be manufactured to run on the tramways and railways. The following description will, I hope, give an idea of the car and its machinery as patented by me on the 24th September, 1873.

In application to the ordinary form of tramway carriage, I utilize a portion of the space below the floor of the car for an arrangement of drums, or barrels, containing the springs, which may be placed transversely in two groups or sets, suitably inter-connected so as to form one continuous volute, acting to generate revolutions of the driving wheel, and thus effect the propulsion of the car. At the terminal or intermediate stopping stations, the means of winding up and re-coiling the springs by a suitable fixed steam-engine, or other prime-motor, are to be provided, rotary motion being communicated by a shaft under the roadway to vertical spindles, and geared wheels, which being thrown into temporary connection for the purpose with the spring barrels, will coil the springs until the requisite tension power is obtained. The means of effecting this temporary connection of the prime-motor with the carriage mechanism may obviously be varied without affecting the principle of thus providing stored up power, self contained, whereby the cars may be automatically propelled. Adequate brake power is also provided so as not only to control and arrest when requisite the spring power, but to hold it in complete suspension when the car is stationary; and furthermore, an arrangement of clutches is interposed between the spring barrels and the driving wheels, whereby the uncoiling motion of the springs, which is constant in one direction only, may be transformed into an ultimate variable rotary motion, giving out the contrary directions as needed for reversing the propulsion of the car.

To obtain distance, the springs are arranged as follows: A, B, C, D, and E, are a series of five springs which are being wound up at A, from the outside, and their action will be as follows:

1st. On the outer end of the spring, A, being moved round, the immediate effect will be that the inner end of the same spring will turn in the same direction; the inner end is connected by a "bush" or arbor, F, to the inner end of the next spring in the series, B, so that the motion imparted to A is communicated to B from the inside. On being wound from the inside, the other end of B follows in the same direction, pulling with the outer end of C, to which it is connected by the pin, G, and thus C is wound from the outside, and the process described in the case of A is repeated till the end of the series.

It will be noticed the power is ultimately given off by the "bush," K, and it is necessary that K should be prevented from turning during the process of winding.

2nd. At any period of the winding all the springs are wound to the same degree of tightness, in fact they are wound simultaneously, and not successively.

3rd. The action during running down is exactly the converse of the above.

4th. To sum up, the action of the series is precisely that of any one single spring prolonged; thus, if in a series of ten springs, each can be wound up twelve times, and give an average pull of five or six cwt.; the pull of the series is precisely the same, but the number of turns is multiplied by 10, or = 120.

I will now describe more fully the means I employ for winding up the spring barrels. At the starting place, or so near to it as convenient, I provide a small 5-horse engine. The shaft of the stationary engine serves to give motion to a belt-wheel, the belt from which passes to a pulley keyed to a horizontal shaft, which shaft is supported in bear-

ings placed below the roadway, and for the sake of convenience enclosed in a metal casting or tube. Close to one side of the tramway, over which the carriage is intended to run, a box is sunk in the roadway, and through this box passes the shaft ; keyed on to the shaft within the box is a spur-wheel, which gears with a spur-wheel carried by a pair of radius arms, which have for their support the shaft. The axle of the spur-wheel is fitted with a sleeve so shaped as to connect with the winding axle of the carriage, and to permit of its instant disconnection thereof when required. The box is fitted with a lid to cover the gearing when out of action ; when it is desired to wind up the spring barrels, the carriage is brought up to the required position ; the lid of the box is thrown back, and the spur-wheel raised so that the sleeve of its axle can be in connection with the winding axle ; the engine is then set in motion, and by means of its connection with the main shaft, it will cause the spur-wheels to rotate, and through the sleeve, or other couplings, give rotary motion to the winding axle, and thereby wind up the spring barrels. To prevent overwinding, a friction-coupling may be introduced at any convenient part of the apparatus, or a means of forcibly disconnecting the sleeve, or other coupling, from the winding axle may be provided. When the spur-wheel has been disconnected from the carriage, it will be returned to its depressed position, and the lid of the box will be closed.

Where the line is three to four miles, I shall require three of the above engines ; one at each end of the line, and one in the middle. Where stationary engines cannot be worked, it is my intention to employ portable engines, which can be brought to the winding-up barrels and the process of winding gone through during the collection of tickets and checking the number of passengers. I think it will be advisable that the places where these "wind-ups" occur should be stopping stations, where passengers may alight from or enter the carriages. These stopping-stations are quite the custom abroad, and it will facilitate the working of my spring-cars if adopted where my invention is used.

On country roads, where long distances have to be traversed, I propose using an auxiliary spring engine. This engine will be fitted with the most powerful springs we can obtain, with full reversing and break power. At convenient sidings on the route, and where it is calculated the spring power under the car will be expended, one of these auxiliary engines will be attached, which will draw the car a considerable distance, where another may be in readiness to continue or finish the journey, as the case may be. Should it be desirable on some lines to have several cars drawn at once, I am of opinion the auxiliary engine can be fitted with sufficient power to draw, at a moderate speed, several such light cars with passengers ; but this is a matter for consideration after my system has had a fair trial on the public tramways, with the style of car at present in use.

I commenced operations about August, 1873, and after trying some experiments on a paper car, with ordinary watch springs, I took out my patent in September of that year. At that time the largest springs made were about six pounds in weight, giving a maximum pull of about 120 lbs., and used for the purpose of lifting "Clark's patent iron shutters." On visiting Sheffield at that time, and seeing several of the most important steel and spring makers, I was informed springs of almost any size might be made, but fresh machinery (and some of a very costly character) and furnaces, &c., would have to be constructed, and none felt inclined to take this risk. I was ultimately introduced to the managers of the Titanic Steel Works, who undertook to provide springs for a rough trial ; finding, however, their plant was incapable of turning out the steel required, they handed the matter over to the "Phœnix Bessemer Steel Company." Mr. Thomas Hampton, the enterprising managing director, called on me, saw my model, and after due consideration, he assured me that with practice, and after experiments were made as to the exact quality of the steel required, almost any kind of springs could be rolled and tempered, and he at once undertook the affair.

Early in 1874 large springs were tested, and the car propelled by them on a short line laid down at my engineer's in the Borough, but after many experiments it was found the original iron barrels,

and the machinery altogether, were too heavy to warrant a public trial of the car; sufficient, however, had been done to show the great stride made in spring tempering since the date my patent was taken out. We had already obtained a few springs with sufficient power to propel a heavily built truck, containing the springs, boxes, and machinery, on the short line at the works; and the following extract from the report by my engineers of a trial which took place at this time will show what power had been obtained.

"The apparatus is at present attached to a strong frame-work of timber, and altogether weighs thirty cwt. On being released it started off at a rapid speed, and struck a plank placed at the end of the line with such violence as to throw itself off the line; it was replaced, thrown out of gear, and run back to the starting place. The experimental truck was then attached by a rope to the Antwerp tramway-car, which weighs thirty-three cwt.; and on being put into gear, started the whole weight of sixty-six cwt. and three persons in the car (which would add about four cwt.) with great ease and smoothness; and at the rate of about six miles an hour. This was repeated twice, and during the whole series of trials the machine was not rewound. On the whole the trial was satisfactory, as proving that the springs were free to exert their full force, and have a sufficient power to propel the car at a proper speed. Had a longer line been available, I have no doubt a much better result as to speed and distance would have been obtained."

Thus it will be seen, spring power in a few months had increased from a pull sufficient to raise up one of Clark's iron shutters (of about 120 lbs. pull) to that required to propel a truck, and one of the Antwerp street cars, weighing altogether about sixty-seven cwt., at the rate of about six miles an hour "with great ease and smoothness."

It was rather an amusing scene, however, this first run. Several of the men at the works were kind enough to volunteer as passengers for the first ride, not thinking the machine would develop so much power. On starting, the clutch was removed, and off the truck went; it, however, to use the words in the above report, "started off at a rapid speed, and struck a plank placed at the end of the line with such violence as to throw itself off the line," together with my unfortunate friends, the workmen, who had so kindly given their services for the first trial. They picked themselves up with much good humor, and soon assisted to replace the car, all present being pleased that the machine had shown itself of so lively a character; and feeling satisfied with such a power properly developed, a great future must be the results of these experiments.

Unfortunately about this period, my friend, Mr. Hampton—who was so energetically at work in producing springs for my invention—met with a very serious accident. He and his groom were thrown out of his carriage, the groom killed, and he laid up with a compound fracture of the leg, and confined to his house for nearly twelve months. Thus, at the moment of success, the whole affair became paralyzed, the experiments put an end to, and I compelled to seek fresh assistance in spring making!

It was the success of the above experiments, however, that supported me in redoubling my exertions in this extremity, and I had before me the noble example of the original promoters of that great work "The Atlantic Telegraph," who after sinking about 2,500 miles of cable along the depths of the broad Atlantic, succeeded in 1858 in transmitting a message from "The Queen of England to the President of the United States," and his reply. The insulation of the wire, however, having become almost immediately faulty, the power of transmitting telegrams ceased, and it was not till 1866, and after several unsuccessful attempts, that the Great Eastern, commanded by the present Sir James Anderson, succeeded in joining a band of communication between the old and new worlds.

After great and many vexatious delays I induced the well-known spring makers, Messrs. George Salter and Co., of West Bromwich, to take up the matter. They laid down fresh machinery, and built new furnaces, securing the experience of their best hands in coiling and tempering large springs, and I am happy to say with great success. During the year 1875 many sets of springs were

made and fixed under the car, which about May last was taken to West Brompton, and tried on the line at the Lillie-bridge Railway works. At one trial we carried about five tons, seven cwt., including car, machinery, and passengers, and at the rate of about seven miles an hour, but having only three barrels at work, instead of twenty-four, we only made a proportionate distance.

Our first run on the rails took place at Lillie-bridge Railway works one Saturday afternoon. The truck with the machinery fixed had, after some difficulty, been placed on the line, wound up and brought to the starting place. It was anything but a pretty affair to look at, painted an ugly iron color; with its peculiar looking spring barrels underneath, and between the wheels, and its long iron brake handle sticking up at one end, a more nondescript looking locomotive had never before, I should think, made its *debut* on the railway. It evidently puzzled the workmen and people engaged on the line, as, although it was Saturday afternoon, and the worksheds closed, a number of men and boys remained for two or three hours, to see what our ugly customer was intended to do; when they discovered a "run" was to take place, and passengers wanted, a rush was made to secure seats, or, as I should more correctly say, stands, for the conveyance was not fitted for passenger traffic. Some sixteen men were soon standing in the truck and holding on to each other ready for starting. At this moment I was much amused at the conduct of the engineer and stoker on an engine shunting a long coal train, who had been requested to clear part of the line for my experimental run. They were sorely perplexed at seeing the men standing on what appeared to them a coal truck in difficulties, but no sooner did they perceive it start off with its motley group, without any apparent driving machinery, than they jumped off their engine and ran after the spring-car, climbing on the back, and taking part in its first journey along the line; and a very merry journey we had on our mongrel-looking carriage, the men and boys laughing outright at the comical appearance of the whole affair, at the same time expressing their pleasure at witnessing this novel kind of propulsion. "Only think, Bill," says one, "this 'ere truck being drove along by watch springs."

A very severe and dangerous illness prevented my carrying out further experiments last year till early in December, when further runs took place with six barrels instead of three, and more than double the distance was obtained. Several serious defects, however, were discovered in the machinery, which had been constructed nearly double the weight necessary in consequence of my machinists being misled by one of the early spring makers as to the actual "pull" the large springs were likely to give. Also, the springs used were found to be too large for the barrels, and bound in unwinding. Of course, I have been to a certain extent working in the dark, as neither the spring makers or temperers had any experience to fall back upon in the manufacturing of such long lengths of steel, and giving them the proper coil and temper best suited for the work it had to do when fully wound up.

When the matter was first laid before the Sheffield steel makers in 1873, it was thought impossible to roll steel bands longer than about thirty to forty feet of "Birmingham wire gauge." The following extracts from the correspondence of the steel manufacturers will illustrate this part of my paper, and which I am afraid, from its necessarily technical character, will prove a dry and uninteresting subject.

Messrs. George Salter & Co., of West Bromwich, write, 1st March, 1874:

"We believe if we make springs of steel, fifty-six to sixty feet long, and six inches wide of nine B. W. G., you will get seven revolutions, and a power of about ten cwt."

To show how things have improved since the above was written, Messrs. Salter have during the last few months produced springs sixty-five feet long, and only four inches wide (instead of six, as named above) giving a maximum pull of over 1,600 lbs.; and as an example of what can now be accomplished, they have tempered a short length of steel three inches wide, giving the enormous pull of 3,150 lbs. This band of steel being one B. W. G., or about one-third of an inch in thickness; this spring when wound up coils as tight as a Coventry ribbon.

Messrs. Jessop & Sons, of Sheffield, wrote on the 24th March, 1874:

"We have rolled seventy feet long, by four inches broad, seven-thirty-seconds thick. We now find we can roll bands 184 feet long, four inches wide, seventeen B. W. G. easy."

Nearly three years have thus been spent in ascertaining the best method of tempering springs, and determining the most useful method of coiling the steel for my purposes. The time, however, has been most usefully employed in trials on my models and the truck and full-sized car at West Brompton. During this period some hundreds of different sized springs have been made and tested, and I may now fairly say all seeming difficulties have been overcome.

In the necessarily short space of time that can be allotted, at such a meeting as the present, to the history of my proposed change of street locomotion, and its relative cost and safety to both passengers and the public generally, I feel I must limit my description to another extract, this time from the report of Mr. George Leach, engineer, and Official Reporter on Machinery at the Paris Exhibition of 1867, and London Exhibition of 1871. Mr. Leach was called in to give his official opinion for the guidance of some gentlemen who contemplated connecting themselves with my patent, which is dated "Britannia Works, Leeds, Oct. 19, 1874." After introducing the subject, Mr. Leach writes thus:

"Although a rumor had reached me previous to our interview, of your proposition to propel tram cars by means of steel springs, I anticipated only a visionary scheme, or a resurrection of antiquated experiments long since defunct in this age of perfected engineering science.

"It required little prescience to remind one that we are daily and constant observers of, and operators in, the manipulation necessary to convey a certain amount of physical force, for the purpose of storing in the tension of a metal spring motive power or energy for required mechanical work.

"Our pocket watches, and other time keepers, besides numerous other common contrivances, familiarize us with the universal adoption of the most practical, and most useful means of providing an accumulation or reservoir of propelling effort.

"The process of winding up a watch, is, for the sake of convenience, brief in point of time, and the force exerted in this operation is proportionate to the power necessary to keep the machinery of the watch in movement during a given period.

"Ten half-turns with the watch key convey from the hand a store of force sufficient for an expenditure of the same equivalent amount of force during twenty-four or more hours, yet the hand, as the origin of the power, is occupied but ten seconds. The time requisite for winding up is but the 8,640th part of that occupied in the subsequent expenditure of the power originally contributed, yet no single unit of this power accumulated during the ten seconds is lost. The effect is balanced, and the well-known mechanical axiom enlarged is recognized, that 'what you obtain in power may be expended by its equivalent in speed.'

"The principles chiefly to be noticed and valued in this system of conveying, conserving or storing power in the tension of springs are:

"1st. Practicability.

"2d. Portability.

"3d. Convenience.

"4th. Economy.

"It may appear singular at first sight that the propulsion of vehicles by means of 'springs,' or rather the 'motive power' stored in springs, has not hitherto been put in practice and carried to a mechanical and commercial success, seeing, as before referred to, there are so many examples where spring power has been utilized.

"There are, however, many reasons why the previous adoption of the system has not been made, and also why before the patenting of your invention other minds have not been so fortunate in working out the solution of this very important question.

"The necessities of rapid transit from distant places, and the carriage of heavy material, have alone sufficed to promote and establish the success of locomotion by steam power as at present exhibited on our railways. The means are suited to all ends, and require no discussion here. Street tramways, however, offer very different considerations, and in en-

deavoring to supply to the cars fitted for the traffic upon the same, the most suitable system of motive propelling power, the inventor is reminded of, and met with totally altered and different conditions.

"Before critically reporting upon either the excellencies or defects of your invention, it is necessary that the exigencies of street railway locomotion should be fairly and impartially stated. These may be enumerated as follows:

"1st. Safety to limb and life.

"Under this head it is not merely the passengers in the cars who must be cared for, but those also occupying other conveyances moving on the public thoroughfares, and in addition to these, the very cattle used in moving the conveyances. Then again, the pedestrians must be protected who may approach the cars. All have equal right of road.

"2d. Security to property.

"Hitherto, all known attempts to propel carriages by steam in the public streets have exhibited the necessity for adopting high and dangerous pressures in order to economize in the least possible space a sufficiency of motive power for the purpose. The reports of the experiences and the casualties attending the experiments with them, dating over forty years back (all honor be to the worthy attempts made by Hancock, Gurney, Ogle, Summers, and others, who attempted to establish steam propulsion on common roads) suffice to indicate the impracticability of using steam.

"The very escape of steam or smoke, or the accidental fall of red cinder, and even the sensation of heat which must be experienced by both passengers and passers by, and the terrors inflicted thereby on the timid and unreasoning beasts of burden are all objections which, forty years ago as now, rendered the use of steam engines upon crowded streets as inadmissible as it would be and is at the present day. In my opinion those who repeat the attempt will also repeat the failures.

"3d. Economy in first cost.

"4th. Economy in working expenses.

"Now by the introduction of your invention I am honestly of opinion that all the advantages enumerated under the last four heads may be secured, and the objections fatal to the use of steam overcome.

"The plan you have invented for connecting a series of springs together into which you can accumulate sufficient force, which can be given out and regulated at will by the conductor of the car (in actuating the driving wheel of the car) is the solution of the problem, and offers the long sought for desideratum.

"The manufacture of such springs, light in weight, reliable and constant in action, and of the necessary strength, has been rendered possible only by the perfection of steel manufacture itself within the last few years.

"The working out of your scheme successfully needs only a careful consideration of detail. Of its practicability you are by your experience already assured. Every particle of the machinery must be so modeled that weight (by the adoption of steel in lieu of iron, malleable cast metal instead of ordinary cast iron, &c.), may be diminished to the minimum, and by this you will obtain, secondly, portability.

"The 'convenience' of your arrangements is acquired by the ability to place the machinery connected with the springs either under the framework of the cars or in a separate tender. The space occupied ordinarily by a pair or two pairs of horses preceding the car as in the ordinary practice will be avoided.

"The 'economy' resulting from your whole scheme is indisputable, and as stated above, whilst adverting to its 'practicability,' careful calculations and planning of mechanical detail are alone requisite to obtain an enormous profit over the present method of propulsion by horse power.

"Your experiments already prove that the power you can store in your series of springs will suffice to propel the car a distance, without stopping, of three miles.

"If, therefore, as is well known, the distances traveled by tram cars without stoppage to put down or take up passengers would rarely exceed many hundred yards, stations might be arranged for winding up the springs at the end of each mile.

"Thus you will insure a sufficient conservation or reservoir of propelling en-

ergy always unexpended in the springs to meet every emergency.

"By suitable and well-known precautions the action of the machinery can be rendered practically noiseless, whilst every possible risk from any accidental breakage of the parts can be assured.

"Instead of applying the ordinary friction brake in stopping the progress of the car, the momentum the car has acquired may, by suitable gearing and simple mechanical contrivances, be converted into available force, and the same given back to swell the stock, so to speak, of consumed power existing in the spring series.

"Many systems of conveying the winding-up power to the cars at the respective stations may be adopted; these, however, would be regulated by local circumstances and by the nature of the gradients in the sections of road to be traversed.

"One stationary steam engine of proportionate power might suffice for conveying power by hydraulic pressure and connections to each of the several stations, whatever their distance apart might be. At these stations the power might be held available at any instant, and with any degree of force, by means of the well-known accumulators, constructed in accordance to the effort required. By these means the imparting of the necessary power to the springs placed on the car may be accomplished in a space of time proportionate to the distance to be run by the car, and comparable to that instanced before in the case of winding up a watch.

In conclusion, I am impressed with the feasibility of your scheme by the fact of its extreme simplicity and its compliance with all the requirements necessary for tramway-car traffic, and I augur for it, if supported by capital and enterprise, a complete mechanical and financial success.

I am, dear sir, yours truly,

"GEORGE LEACH.

"Official Reporter, Paris Exhibition, 1867.

"Official Reporter, London Exhibition, 1871."

As regards its application to the public thoroughfares, I can add little to the above report, and feel the writer has fully placed the value of my invention before those interested in tramway property. I will merely remark that I trust in a short time to see the spring motion applied to a light steel corrugated carriage, to run on the asphalt roads, or where such roads are not convenient, on the asphalt bands, as lately proposed by Mr. Edwin Chadwick, a full report of which appeared in your Society's *Journal* of the 25th June, 1875. On page 26 of that paper a diagram is given of these asphalt wheel tracks.

My spring makers, Messrs. Geo. Salter & Co., have just completed the springs and machinery for propelling a car to run either on the asphalt roads or the ordinary tramways. Two sets of wheels have been made, which can be changed as required for either mode of transit. The car has been built especially for this machinery, the barrels placed longitudinally under the carriage, and in two sets, which can be worked successively or simultaneously, as the case may require. The spring power can be shut off at any time during transit, so as to take advantage of the impetus given to the car, and can be immediately applied when needed; full brake power is provided, also the reversing gear, which has been greatly improved since the experiments made at Lillie-bridge.

The following comparison between the car tried at West Brompton, and the one under construction by Messrs. Geo. Salter & Co., will show the improvements made during the last few months both in spring power and the style of carriage to be used either on the ordinary tramways or asphalt roads.

The body of the car tried at West Brompton weighed about 23 cwt.	The body of the car now constructed weighs 4 cwt.
The springs each weighed 120 lbs.	The springs each weigh 85 lbs.
The springs were each 65 ft. long, and 4½ inches broad,	The springs are each 38 ft. in length, and 4 inches broad,
And had a maximum pull of 950 lbs.,	And have a maximum pull of 1,600 lbs.
Giving (each spring) 4½ revolutions.	Giving each spring over 7 revolutions.
These springs required boxes of 22 inches diameter.	These springs require boxes of 14 inches in diameter.

Thus it will be seen the new car is about one-sixth of the weight of the one

experimented upon last year, while it has nearly double the power and revolutions in the springs, with one-third less weight in springs and machinery. The barrels being arranged longitudinally under the car, give more room for the action of the brake and reversing gear.

It is my intention to test this car both on the tramway and asphalt roads, when it will be sent over to Antwerp for trial, on a line in that city, and if satisfactory, will be at once adopted for the tramway traffic in Belgium.

As regards the important item of cost of machinery for driving a car by my spring motors, and the annual cost of working a car on any of the London tramways by horse-power, it is estimated the expense of the latter is about £750 per annum, which includes keep of fourteen horses, wear and tear and loss of stock (which I hear is very great), harness, stablemen, veterinary charges, rent, &c.; whereas it will be seen, from the following estimate, my car can be worked at less than one-third of this annual expense :

The machinery for each car (which it is estimated will last many years), about £200.	
Interest on this outlay at ten per cent....	£20
Proposed royalty on each car using my invention per annum.....	100
Wind-up steam apparatus divided among cars on one of the metropolitan tramways, say per annum.....	50
To make up round numbers, may be added for repairs, lubricating, and wear and tear, per annum.....	30
Total expense of spring-car per annum	£200
Against £750 per annum for horse traction.	

The price of the spring motor (£200) is not carried forward into the yearly charges, as it will form part of the rolling stock of the company. The "winding up" is managed by a five-horse power-engine in about two minutes. Where the line is over three miles it will require three engines, which will be capable of winding up at least 200 cars daily.

Before concluding, I think it right to refer to some of the objections made by those interested in tramways, and my replies to the same. The first I will notice is the danger of breakage to steel springs during the severe winter weather. I at once put myself into communication with Mr. George Ede, the Government Inspector of Steel at the Woolwich Arsenal, who is well known for his experience on all matters connected with steel. I quote his reply :

LETTER FROM MR. EDE, GOVERNMENT INSPECTOR OF STEEL IN THE WOOLWICH ARSENAL.

WOOLWICH, October 28th, 1874.

SIR: In reply to your letter asking my opinion as to whether severe winter would act unfavorably upon your springs, I beg to say that so far as my own theoretical and practical knowledge of steel, and observation enables me to judge, no degree of cold that we ourselves could stand could in the slightest degree act unfavorably upon your springs, but on the contrary, would act favorably upon them for your purpose. Winter (cold) as is well known contracts the material, consequently the particles are brought into closer contact with each other, and thereby increases the rigidity and power of the material. The difference, however, is so slight that it would not be worth taking into consideration.

I remain, Sir, obediently yours,

GEO. EDE.

E. H. Leveaux, Esq.

To the objections of turning sharp curves, stopping and starting, springs losing their elasticity, running off the rails, &c., I handed a list of them to Mr. Downs, who had constructed my models, &c., and made the drawings for the machinery of the large car, and desired his report on the same, and which is as follows :

REPORT FROM MR. DOWNS OF MESSRS. NEWTON & SONS.

Patent Office, Chancery Lane.

DEAR SIR : I regret that important business prevented my being present at your trial of model tramway-car on Saturday. I have carefully considered the list of objections to your proposed system which you handed to me, and I can see in them nothing for which provision has not been made in the design as it now stands. With respect to the first objection, viz.:

1. *Turning Curves.*—Curves of large radius will not materially retard the wheels, and where curves of small radius occur, such as for instance, the turning corners of streets, one plan at present in

use with short curves is to run the wheels in a groove on the inner curve only, and at the outer curve the wheels run on their flanges on a flat rail only; another plan would be to mount one of the axles so as to radiate from the center of the curve, and under the control of the driver.

2. *Stopping and Starting.*—The spring power is divided into two sets, each of which is under the control of the driver, who can, by means of the starting levers, throw either or both sets of springs into gear at will, thus doubling the power.

3. *Springs Losing their Elasticity.*—When springs are properly tempered there is no loss of elasticity if they are not strained beyond a certain point. The diameter of the barrels and arbors must therefore be so proportioned as to prevent undue strain being put upon the springs when wound up tight round the arbor.

4. *Cars Running off the Rails.*—In the event of a car running off the rails, the wheels still remaining on the ground, the ground would act as a brake. The power can instantly be shut off, and the car replaced upon the rails, inclined planes or wedges for that purpose being now in use on the "North Metropolitan Tramways." I believe each car is provided with them.

5. *Noise of Machinery.*—With the slow rate of motion required the wheels will run almost noiseless, the last pinions running only at seventy or eighty revolutions per minute, and the rest of the train of wheels seven or eight revolutions per minute.—Yours truly,

W. Downs.

To E. H. Leveaux, Esq.

I must, in conclusion, once more crave your consideration for addressing you on engineering matters, as I feel my simple description of machinery employed for carrying out this invention will sound strangely in the ears of many assembled here this evening. I have also to ask your kind consideration and indulgence in respect to the delivery of this paper, feeling the effort of speaking for so long a time increases my difficulty in bringing this important subject before you in as favorable a manner as I should have desired to do. I must take this public opportunity of expressing my obligations to those practical engineers who have guided me by their advice and assistance in arranging and manufacturing the machinery necessary for the development of my invention.

My models have been made by Mr. W. Downs, of Messrs. Newton & Sons, patent agents, from both of whom I have received the most valuable advice, from the time I took out my patent to the present day. My friends, Mr. Thos. Hampton, of the Phœnix Bessemer Steel Works, Sheffield, and Messrs. George Salter & Co., of West Bromwich, have done their utmost to develop spring making for the use of my invention. Mr. Thomas Middleton, of Loman Street, Borough, took an early interest in my work, and by his kind and valuable co-operation many experiments were carried out at his works, and on the West Brompton line of railway. Indeed I feel, as an outsider in mechanical experience. I have been very fortunate in surrounding myself with such valuable aid and assistance. Thanking you for your kind attention to my paper, I now beg leave to conclude, and will exhibit sample springs for your inspection.

TABLE SHOWING POWER OF SPRING REQUIRED TO PROPEL CARS ON TRAMWAYS AND RAILWAYS.

Total Weight of Car, Machinery, and Passengers.	Draft on circumference of Barrel.	Effective Draft on Car at Drawing Wheel.
2 Tons	288 lbs.	24 lbs.
2½ Tons	360 lbs.	30 lbs.
3 Tons	432 lbs.	36 lbs.
3½ Tons	504 lbs.	42 lbs.
4 Tons	576 lbs.	48 lbs.
5 Tons	720 lbs. ...	60 lbs.

From the above table it will be seen it requires a draft of 720 lbs. on barrel to propel one of the large street tram cars full of passengers.

Springs have already been manufactured, giving a draft of 1,100 lbs., and Messrs. Jessop, of Sheffield, have rolled a band of steel which, when tempered into a spring, will give at least three times as much power as above. It will be thus seen that the development of spring power is now only in its infancy, and when a commercial demand arises for large springs, the manufacturers will lay down fresh machinery, whereby they will be able to roll steel bars of enormous lengths and thickness. Messrs. Jessop, of Sheffield, write, March 24th, 1875,

they had rolled a band of steel 184 feet long, and four inches wide—17 B. W. G. This band of steel is nearly four times as long as the springs now propelling the machinery at West Brompton.

When Sir John Brown, of Sheffield, commenced making his armor-plates some twenty-five years back, six inches was then thought the maximum that could be accomplished; at present, the Sheffield houses engaged in this trade are manufacturing plates over thirty-two inches in thickness.

Messrs. George Salter and Co., West Bromwich, write under date March 9th, 1875, "They will be very large springs (seventy feet long, six inches wide), but we do not see why the steel manufacturers should not send larger still. We can temper almost any size."

ON THE YIELD OF WELLS SUNK IN THE CHALK IN THE CENTRAL PORTION OF THE LONDON BASIN.*

By Mr. EDWARD EASTON.

The question of Water Supply to London is so important and so interesting to engineers, that the writer does not hesitate to place before the Members of the Institution some facts, which in the course of a long experience he has gathered, and conclusions he has arrived at, in the hope that the statement of them may elicit additional information and valuable opinions on the subject. The geology of the London Basin has already been most ably and fully described by Professor Prestwich, Mr. Whitaker, Professor Ansted, and others; and it is not proposed to refer to it, except as far as the great divisions of the stratification affect the water-producing power of the basin generally.

The two great water-bearing divisions are: first, the chalk denuded of superincumbent strata (except gravel), which receives the rainfall direct; secondly, the chalk covered by the tertiary deposits, which receives the rainfall, partly from the denuded chalk, and partly after its passage through the pervious beds underlying the London and plastic clays. It is to the consideration of this latter division that the present paper relates, and especially to that portion of it which is situated in the middle of London, within a radius of four or five miles from Charing Cross.

The chalk under London is always spoken of as taking the form of a basin; and this is strictly correct, as far as regards both its configuration of surface and lines of stratification along sectional lines from north to south. But it resembles a basin with a lip or spout to it in the other direction from west to east, the spout or outlet being the valley of the Thames below Woolwich, where the river after passing through the tertiary strata resumes its course through the chalk itself.

Were it not for two disturbing causes, it would be easy to trace the rainfall from its point of reception into the chalk to its outlet into the Thames, and so on to the sea; and an approximate estimate might be formed of the quantity so passing. But in the first place it is very difficult to determine the amount of obstacle offered by the deflection of the chalk to such a depth as it assumes under the tertiary strata, a depth varying from 100 to 300 feet; and in the next place there occurs a great fault in the strata on the east of London, which has a very marked effect upon the outflow of the water.

It is not possible to describe this fault in shorter or clearer language than that used by Mr. Whitaker* :—"The most important fault in the London basin is that along the valley of the Thames below London, with a downthrow on the north sometimes to an extent of about 100 ft., and perhaps more, which may indeed have had some effect in determining the course of part of that valley. It

* From a paper read before the Institution of Mechanical Engineers.

* Memoirs of the Geological Survey, Vol. IV, part 1, page 353.

was seen in section in two railway cuttings south of Deptford, is proved by well sections at Greenwich, is lost sight of (? under the river) at Woolwich, is again shown farther eastward, again lost under the river, and last occurs on the northern side of the Thames near Purfleet and Stifford. In thus attempting to trace this fault for so long a distance I must be understood to speak with a little doubt, as there are two breaks in the chain, and as on the north of the river the beds are so much hidden by alluvium and gravel. In Mr. Mylne's geological maps of London no such line of fault is shown, but that at Greenwich is made quite distinct from that at Abbey Wood. I was quite unable however to trace any such lines of fault as as those on Mr. Mylne's map, and it seemed to me much safer to connect the three separate exposures of Greenwich, Abbey Wood, and Stifford, in a gentle curved line."

The writer has quoted the whole of the passage, because it rather contradicts the facts published by Mr. Mylne in his careful map of the London Strata. Mr. Whitaker further says that "there may be other faults in this disturbed tract" (south-east of London), but that "acting on the safe principle in geological mapping, not to draw a fault unless it is actually seen," none have been marked on the geological map of England.

The fault thus described, combined with the fact of the chalk being disturbed, has caused a sudden alteration in the level of the water in the chalk; for whereas in the wells in Bermondsey on the south of the Thames, and Whitechapel and Shadwell on the north, the normal level of the water is from seventy to ninety feet below Trinity high-water mark, the wells at Greenwich and those of the Kent Water Works on the south, and at Grays and other places eastward of the fault on the north side, have their normal water-line generally at about mean-tide level, or about ten feet below Trinity.

The other disturbing element in the flow of the water, as distinguished from the phenomena to be observed in what the writer will term pure chalk districts (such as the Brighton Downs for example), is that described by another eminent geologist, Professor Prestwich.* "With reference more particularly to the condition of the chalk underlying the tertiary strata, it is evident, in the many movements of elevation and depression which the crust of this part of the earth must have undergone, that those strata which form the immediate surface must have been far more shattered and fissured than those which are covered by a great weight of superincumbent deposits: the one portion would be extensively fissured and creviced, whilst the other would remain comparatively unbroken and entire. Therefore we cannot expect to find in the deep-seated mass of chalk beneath the tertiary strata the same facilities for the transmission of water as those which evidently exist in it where it constitutes the surface of the country."

Were it not for these disturbing elements, the flow of water in the chalk under London would doubtless follow more closely the general laws which govern it in pure chalk districts.

In the case of Brighton for instance, the rain which falls on the surface is to a greater or less extent, according to the period of the year, absorbed into the body of the chalk, and finds its way straight to the sea, partly through vertical fissures made during the course of ages in the solid rock itself, and partly along the horizontal lines of flints, which frequently in that district form unbroken beds of very considerable extent. The whole of the rainfall, except that absorbed by vegetation or given off by evaporation, percolates into the chalk, and has its chief outlet into the sea: just as, in the case of the London basin, its chief outlet would naturally be towards the river Thames at Deptford and below. When the chalk becomes full, the surplus water runs out at springs, which break out all along the great escarpment at the northern boundary of the South Downs, at Poynings, Plumpton, and in the Clayton tunnel of the London and Brighton Railway: just as, all round London, the overflow of the chalk finds its vent in the springs forming the rivers Wandle, Ver, Colne, Wendle, &c. But whereas the main body of water at Brighton runs into the sea underground, and only the surplus water finds its way

* Water-bearing Strata of London, p. 65.

into the open country: in the case of the London basin there is good reason for supposing that the great bulk of the rainfall on the chalk and strata feeding the chalk, situated to the westward of the fault above mentioned, runs out at these streams, and that only a comparatively small portion finds its way into the chalk under London. This view is strongly corroborated by the fact that,—whereas in London proper, where the chalk is covered with thick tertiary deposits, it is rare to meet with any well which will yield more than from 300,000 to 600,000 gallons daily (there is only one well the writer is acquainted with doing more than this, namely that of the Government Water Works in Orange Street),—the wells and boring of the Kent Water Works give quantities varying from 1,000,000 to 5,000,000 gal. daily.

The fissures in the chalk being comparatively small, it follows that the inclination of the surface of the water will be such as to give the necessary head for the delivery of the water through them in proportion to their size. This rate of inclination in the Brighton chalk is as nearly as may be forty feet per mile. The writer has made careful observations as to this, the result of which was that the level of the water in wells situated in a straight line northward from the center of Brighton to the Clayton spring described a flattened curve, which varied in its shape according to the season, but approximated to the rate of inclination above given. A record was kept at the Brighton Water Works for upwards of twelve years, which showed that the depth of water level in the wells varied with the rainfall. Speaking generally, the depth of water level in the wells at Brighton was at its maximum in March each year, and the minimum was in October to December; but this was dependent upon the season, it being observed that the curve formed by the depths of the water followed that of the rainfall at an interval of about four months. Very much the same phenomenon takes place in the London basin, where again on the average the lowest time in every year is March, and the highest November to January.

The disturbing causes have produced also another result in the case of the London basin, namely the uncertainty of finding water in any quantity. This is particularly shown by the difference in the yield of the well at Trafalgar Square and at Combe & Co.'s Brewery in Long Acre, the former giving above 600,000 gallons daily, whereas the latter at the distance of little more than a mile does not afford a supply of one-tenth the amount, although the water level is lowered very considerably more.

It is very difficult to determine also how much of the water obtained from the wells sunk through the tertiary strata into the chalk is derived from the chalk itself, and how much from the sands between the plastic clay and the chalk. At many places the quantity from the sands is very much in excess, as for instance at Truman & Hanbury's Brewery, where out of a daily yield of 120,000 gallons, only 10,000 gallons, or one-twelfth of the whole, comes from the chalk itself. The writer's opinion is that in every well sunk in the center of the London basin, where the chalk is covered by the tertiary sands, there is a very considerable admixture of water from these sands with the chalk water proper, if indeed this adxmixture is not quite general all over the district. The chief reason for coming to this conclusion is that,—whilst the analysis of water derived from denuded pure chalk invariably shows a hardness, according to Dr. Clark's test, of from fourteen to eighteen degrees, arising to a very great extent from the presence of carbonate of lime and to a smaller extent from chloride of sodium,—the water obtained from boreholes or wells sunk through the tertiary strata is generally soft, and varies from three to eight degrees. This does not arise from the absence of mineral matters in solution, so much as from the presence of alkalis which neutralize the hardening effects of the salts. Thus, whereas the average analysis of pure chalk water would be somewhat as follows:

Carbonate of Lime.....	13.00	gr. per gall.
Sulphate of Lime.....	1.20	"
Chloride of Sodium...	2.50	"
Silica	1.00	"
	17.70	

or say 18 gr. per gall.,—the average analysis of the deep-well water under the tertiary strata would be

Carbonate of Lime....	3	to	8	gr. per gall.
Carbonate of Magnesia.	1½	to	2	"
Carbonate of Soda.....	6	to	18	"
Sulphate of Soda 24		to	6	"
Sulphate of Potash....	1	to	13	"
Silica.....	½	to	1	"
Chloride of Sodium...10		to	20	"
	46		68	

or from 40 gr. to 70 gr. per gall.

Another point to be observed in connection with all these wells is that the level of the water in them is steadily lowering, as the sinking of new wells in the district causes a larger amount to be drawn from the strata. This has been observed in nearly every well which has been steadily worked; and several cases are known where wells have become disused, owing to their having run dry.

From all these facts the writer draws the conclusion that the passage of the water through the fissures of the chalk under the tertiary strata is very much impeded; and that, although there is an immense surplus of rainfall percolating into the chalk all round London, comparatively little finds its way into the chalk beds beneath the center of London; and that what does so pass is very much mixed with water which has either come direct from the outcrop of the tertiary sands and through them into the wells, or has in its passage from the upper levels of the underlying chalk to the lower parts of the stratum gone through some of those sands. It is evident that no great quantities of water can be expected under London itself, certainly not more in the writer's opinion than will be wanted for manufactories and large consumers; and that any great addition to the general supply of the metropolis from the chalk must be looked for from the outlying districts where that stratum is denuded.

VENTILATION OF RAILWAY TUNNELS.—At a meeting of the Institution of Civil Engineers, this subject was brought forward in a paper by Mr. G. J. Morrison.

The author claimed to have shown that tunnels less than half a mile long, with large open spaces at the ends, might be left to themselves, even when traversed by frequent trains at short intervals; that in tunnels up to about seven miles long natural ventilation might be trusted to, provided they were advantageously placed, and the traffic was light; and lastly, that with a heavy traffic of both passengers and goods, where the number of trains approached one per hour in each direction, a tunnel of seven miles without shafts was the longest which could be kept wholesome even by artificial ventilation if ordinary locomotives were used. The different methods of exhaustion, which were considered best for the purpose of ventilation, were then considered, and various kinds of fans referred to. Means for removing the impurities generated by an ordinary locomotive, were discussed. One pound of lime was capable of absorbing about three-quarter lb. of carbonic acid, so that with about 150 lb. all the carbonic acid given off per train mile would be absorbed. The hot-water locomotive had been suggested as fit for such work, and boilers with a receptacle inside for a mass of red-hot iron or heated fire-bricks; but these and the compressed-air engine were shown to be inadmissible. The pneumatic system would involve all the trouble and expense of ventilation, and would not give as great facilities for working as many others; and the difficulties attendant on the atmospheric system were detailed. It was contended that the rope presented the most feasible method of working long tunnels. Finally, the author concluded:

(1) That when long tunnels without shafts had to be ventilated, a current of air should be caused to pass through by means of a fan placed near one end, that end being closed by doors; (2) that for a given amount of traffic the power required to ventilate long tunnels varied as the fourth power of the length; (3) that when a long tunnel had to be ventilated, it was more advantageous to have a double-line tunnel, with trains in both directions, than two single-line tunnels, each having trains in one direction only; (4) that for every tunnel there was a limit to the amount of traffic that could be carried by locomotives, beyond which ventilation became impossible; that when this limit had been reached, some tractive power other than coal-burning locomotives must be employed; and that this limit could not be definitely fixed, but that for a tunnel of twenty-two miles in length, it did not exceed a total of twenty trains per day.

STABILITY OF ARCHES.

By LEWIS S. WARE, C. E.

Written for Van Nostrand's Engineering Magazine.

In a lecture given by Mr. Tresca, Professor at the Ecole Centrale in Paris, he gives Mr. Durand Claye's method of proving by a geometrical construction that any given arch *is* or *is not* in a good condition of stability.

To make this as clear as possible to the reader, I thought it well to give a few preliminary problems; which will also have the advantage of making more precise some of the indications which will follow:

EQUATION AND PROPERTIES OF THE FIGURATIVE CURVE COMPRISING ALL PRESSURES NORMAL TO THE KEY STONE.

A any point on C D. h is one point of the unknown curve obtained in taking A h=F H; we can have as many points as we like in the same manner. If we wish the pressure N normal to the joint C D at A to give a curve passing by a, it is necessary that the result of P and N should pass at this point.

Remark.—Prolonging $a\,l$ = F K. $a\,l$ will represent the action exerted by the upper stone on $C_1 D_1$.

Equation of the curve, Fig. (1):

($o\,x$ and $o\,y$ the axes).

y=A h=F H=F P tang. α=P tang. α

$a\,b$ constant for all curves passing at a; (α) angles which varies with A, and is given by the relation

$$\text{tang.}\,\alpha = \frac{a\,b}{\text{F}\,b} = \frac{m}{x}$$

$$\text{Then } x\,y = \text{P}\,m \quad (1) \qquad y = \frac{\text{P}\,m}{x}$$

From this we see the curve of the points h conjugated with a is an Equilateral Hyperbola.

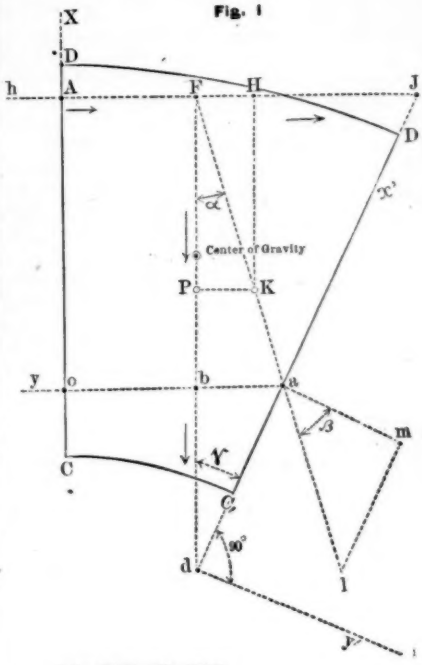
LIMIT OF THE AREA OF PRESSURES ON THE KEY JOINT COMPATIBLE WITH THE GEOMETRICAL EQUILIBRIUM.

If I had made my calculations starting from the extreme points C and D, on the joint C D, we would have had two other Equilateral Hyperbolas in which the equations would only differ from (1) in the value of (m).

The area which exists between these two curves is the Locus of the extremity of all lines, representing the pressures that can be exerted on the joint C D.

This area we will call A.

Fig. 1



A h=F H=N=P K

$a\,l$=F K

$a\,b$ constant

F P=P

N pressure normal to the joint C D

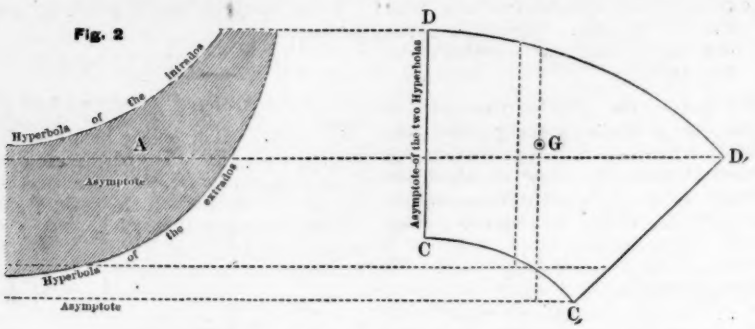
P weight of the stone C D C_1 D_1

CURVE CORRESPONDING TO THE SECOND JOINT.

If we limit the Locus of all the points m obtained in projecting $a\,l$ on the perpendicular to $C_1 D_1$, corresponding to the pressures passing by a same point A of the joint of the key stone, we will find again a curve which is a hyperbola.

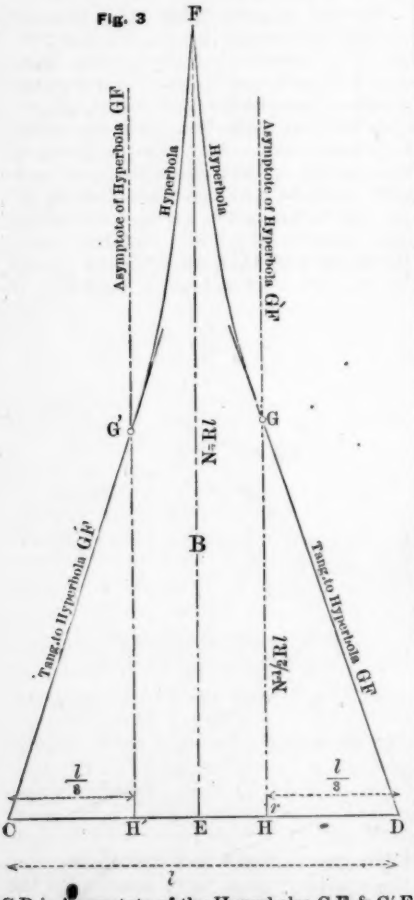
Equation: (dx'; and dy', axes)

Fig. 2



We find for the force passing at a

Fig. 3



C D is Asymptote of the Hyperbolas G F & G' F

$$y' = a\,m = a\,l \cos.\ \beta = \mathrm{F\,K} \cos.\ \beta$$

$$\text{Cos. } \beta = \sin.\ (\alpha + j) \qquad \mathrm{F\,K} = \frac{\mathrm{P}}{\text{Cos. } \alpha}$$

then

$$y' = \mathrm{P}\frac{\sin.\ (\alpha + j)}{\cos.\ \alpha}$$

$$= \mathrm{P}\,(\text{tang. } \alpha \cos.\ j + \sin.\ j)$$

y' varies with α. The elimination of α is necessary.

$$\text{tang. } \alpha = \frac{a\,b}{\mathrm{F}\,b} = \frac{a\,b}{\mathrm{F}\,d - d\,b}$$

$a\,b = x' \sin.\ j$
$b\,d = x' \cos.\ j$
F d put $= n$

$$y' = \mathrm{P}\left(\frac{x' \sin.\ j}{n - x' \cos.\ j}\right\} \text{Cos. } j + \sin.\ j\Big)$$

After reducing

$$y' = \frac{n\,\mathrm{P} \sin.\ j}{n - x' \cos.\ j}$$

Equation of an Equilateral Hyperbola easy to represent.

What has been said of the extreme points C_1 and D_1, when we consider the joint $C_1 D_1$ can now be repeated in speaking of C D (joint of the key stone). We obtain as before two hyperbolas between which exists an area (we will call A_1).

OBSERVATION.

The areas (A) and (A_1) have in reality only one meaning; any pressure limited at any given point of the area (A) on the joint C D has its homologue at one point of the (area) (A_1). The contrary rule is also true. It is for that reason. Mr. Durand Claye, of late, does not consider the area (A), which is entirely expressed in considering its conjugate (A_1) which we will make use of in the future.

FIGURATE CURVE COMPRISING ALL NORMAL PRESSURES, COMPATIBLE WITH THE RESISTANCE OF MATERIALS OF THE ARCH.

We must now consider the curve in which the ordinate passing from any point r of the joint C D representing the normal pressure in virtue of which the greatest pressure R per square inch on the element having the highest charge of the joint ought not to surpass R pounds. This curve is found in the following examples:

1° *When the distance* D r *is less than* $\frac{1}{3}$ *of the length* l *of the joint* C D—(see Fig. 3). N r direction of the normal force; the point having the greatest pressure is D. We will limit the force N corresponding to a pressure $p = R$ per square inch at the point D. In this case we will consider the force N as if applied at the extremity of r of the first $\frac{1}{3}$ of the contact surface the width of which $3x =$ 3 D r, and applying the law of repartition we ought to have for D

$$p=R=\frac{2N}{3x} \qquad N=\tfrac{3}{2}Rx$$

The force N is given for each point by a function of the 1st degree.

It is a straight line in which for $x=\frac{1}{3}l$ we have

$$N=GH=\tfrac{3}{2}R\times\tfrac{1}{3}l=\tfrac{1}{2}Rl$$

2° D r *is situated between* $\frac{1}{3}l$ *and* $\frac{1}{2}l$.—Applying directly the law of repartition of so called trapeze for the border, the nearest to point of application of the force; that is to say

$$\left.\begin{array}{l} p=R \\ w=l\times 1=l \\ a=l-x \end{array}\right| \quad R=\frac{2N}{W}\left(\frac{3a}{l}-1\right)$$

$$R=\frac{2N}{l}\left(2-\frac{3x}{l}\right)$$

Equation of a hyperbola.

OBSERVATION.

We find exactly in the same manner an area (B_1) on the joint C_1D_1; it is necessary to remark that these areas have each a signification distinct, and they are obtained independently of each other—and concern only the joint on which they are drawn. They are the Locus of the normal pressures exerted on each joint *without* the pressure passing in any point the limit R per sq. yard taking into consideration the material used. If, on the joint C_1D_1 we construct A_1 and B_1, we shall have an area (C_1) (see Fig. 4)

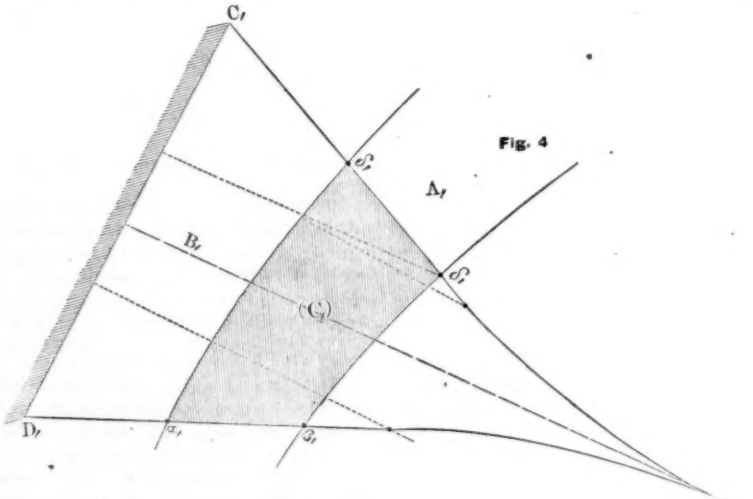


Fig. 4

common to the two. We can affirm that there will be no other solution compatible at the same time with the conditions before mentioned, which are necessary for the stability, than those limited by the area (C_1).

GENERAL EXPLICATION OF "DURAND CLAYE'S METHODS."

The area (C_1) being known, every normal pressure comprised in this area comes from a corresponding one on the joint C D; we can call (C) the area which comprises all these new pressures; we must remark that the curves $\alpha\beta$ and $\delta\delta$, correspond to the two horizontals of the points C and D. We must consider in regard to the joint C D two areas limiting the pressures; area (B) of the pressures compatible with the limit of the resistance of materials on the joint C D, and the area (C) conjugate of the area (C_1).

There will be no other pressures of stability on the joint C D than those contained at the same time in the area (B) and the area (C); we will call (D) the part which is common to the two; we can say that this area *residue* (D) is, when we consider the entire stone C D C_1 D_1, the Locus of all pressures compatible with the two conditions of stability already spoken of, and that it contains all solutions compatible with the two conditions of stability of the first stone, taken only into consideration. If we consider the first joint C D with another (C_2D_2), we will have an area (D_1). We can do exactly the same for all the other lines of joint and the area common to all the areas *residues* (D), (D_1). (D_2) contains the vertices of all the pressures compatible with the conditions of stability. The final area gives the ensemble of all the solutions.

INTERPRETATION OF THE RESULTS OBTAINED IN APPLYING THIS METHOD.

If we call (E) this final area, we will have previous indications on the stability of an arch.

1° E=O, there is no solution compatible with the stability of the arch. An arch built under these conditions would surely fall down.

2° If (E) is only a point there would be only one way of repartition possible.

3° If E is limited by a triangle or a quadrangle whose sides are curves; each point of these areas correspond to a position of equilibrium.

4° If this area is too big, we can conclude that the stone has been used in a wasteful manner; we should try and reduce the size in diminishing the thickness of the arch, or in using materials less resisting.

I have had many methods, but none of them were as simple as the above.

STONE TRAMWAYS IN ITALY.

From "Journal of the Society of Arts."

TRAMWAYS consisting of blocks of stone laid longitudinally are in general use in Northern Italy, not only in the streets of the principal cities, such as Turin, Milan, Verona, &c., but even in the smaller towns, as Chivasso, Mortara, Vigevano, &c.

These tramways are not intended to suit one particular class of traffic, using specially constructed carriages, as is the case in London, Paris, Vienna, and many other towns on the Continent, but are intended to be used by every kind of vehicle, and for this reason must be regarded as a system of street paving rather than that of street railway, as would be understood in England.

This being the case, the cost of laying down these lines, and their maintenance, naturally belong to the municipality, and is paid for out of the town revenue obtained from octroi duties and other local taxes.

A street railway was opened for traffic a few months ago at Turin, by a company who have a concession from the municipality enabling them to lay iron rails in the street for the exclusive use of tramway cars with flanged rails. There are several other street railways in Italy, but these must be considered as quite distinct from the stone tramways, or rather the system of paying which is adopted in almost every street in Turin and Milan.

The stone trams being used by every

class of vehicle met with in towns, it is quite impossible to obtain any reliable data as to the superiority over other systems of tramways, or of paving, as regards amount of tractive power, wear and tear to wheel tyres, &c., but it is very evident that on a smooth, even surface, which presents no impediment to the passage of the wheels, the tractive force required to haul a given load a certain distance in a given space of time would be less than that required over an ordinary paved road, and the wear and tear to wheel tyres considerably reduced, as the ends of the granite blocks being accurately fitted together, and forming one continuous plane, present but little resistance to traction.

This is impossible to obtain in ordinary paving, and in consequence the joints between the stones present irregularities and impediments to the passage of vehicles.

There is no doubt that vehicles on a stone tramway run more freely than over the stones in London, as this is verified from the sound whilst riding, which is considerably less in a Turin, or Milan *cittadino* than in a London cab, but greater than in a Paris *fiacre* over an asphalte surface, which reduces the vibration to a minimum.

The stone tramways have an advantage over the ordinary iron street tramways, as they can be used by every description of carriage, and can accomodate a far greater amount of traffic, by giving freedom to vehicles to leave the tram when needed; and these are not helpless when off the track, as is the case with the tramway car.

The stone tramways in Italy consist of blocks of granite, laid parallel to each other, at a distance of 0.70 (28 inches) apart. These blocks are usually 0.60 (24 inches) in breadth, and 0.20 (8 inches) in depth, and are bedded in a layer of sand. The space between the blocks and remainder of roadway is paved with rounded river-washed stones (*ciottoli*) from the Po, Ticino, or other torrents.

The roadway is usually formed with a slight inclination towards the centre, and the space between the trams serves as a channel to receive the surface water, and is provided at suitable intervals with stone gratings to allow the free flow into the sewers.

The granite blocks are not laid perfectly horizontal, but should be set 0.01 ($\frac{3}{8}$ inch) lower on the inner side than at the outer. The intermediate channel should be slightly concave, forming an arch of circle, with chord of 0.07 ($2\frac{3}{4}$ inches) and versed line of 0.037 ($1\frac{1}{2}$ inches).

The foundation of the roadway consists of a layer of screened gravel, not less than 0.15 ($5\frac{3}{4}$ inches) in depth, which should be well rammed and watered to obtain a compact mass. A layer of sand 0.05 (2 inches) in depth, is spread over the gravel to form the bed for the granite blocks. The surface of this layer should be carefully smoothed down to the exact slope which it is intended should be given to the roadway.

The granite used at Milan is brought from the quarries of St. Fedelino, near Chiavenna, on the Lake of Como, and is specially adapted for the purpose from its hardness and durability. The granite of the Lake Maggiore and Mont Orfano is occasionally used, but it is not so suitable for the purpose, being somewhat softer. As it is more readily worked it is cheaper, and also the cost of carriage to Milan is less. The granite is brought by water, and the cost of transport from the Lake Maggiore is 5 francs (4s.) per ton, and from the quarries on the Lake of Como 6 francs (4s. 10d.) per ton.

The specific gravity of the granite of St. Fedelino is 2624, and that of the Lake Maggiore 2660.

The blocks of granite, as specified by the municipality of Milan, should be 0.595 (nearly 24 inches) in breadth and 0.20 (8 inches in depth,) and in length of not less than 1.50 (nearly 5 feet), excepting on curves and at junctions and crossings, where blocks of special form are required.

The upper surface of the blocks should be dressed perfectly even, and the ends accurately squared, so as to form a perfect joint with the next stone.

The stone gratings for the gullies, are also of granite, and are 0.80 (32 inches) in length; their upper surface should be concave to correspond with the channel between the trams. They are pierced with two holes or slots, 0.30 (12 inches) in length and 0.038 ($1\frac{1}{2}$ inches) in width, and 0.242 (9 inches) apart.

After the granite trams are placed,

the remaining part of the roadway, with the exception of the foot-ways, is paved with river stones (*ciottoli*) from the Ticino or Adda. These stones should be egg-shaped, from nine (3½ inches) to twelve centimeters (4¼ inches) in diameter at one end, and from six to nine centimeters (2⅓ to 3¼ inches) at the other, and from twelve (4¼ inches) to fifteen centimeters (5½ inches) in length. Care should be taken in setting them in regular courses.

After being well rammed into place with a wooden rammer, the surface should be watered and covered with a blinding of sand about two centimeters in depth, so as to fill the joints by degrees.

When the blocks become worn, their surface should be redressed by the stonemason, and if any settlement has taken place they should be rebedded.

On steep gradients it is often necessary to add a series of diagonal grooves across the trams, to prevent the slipping of horses and the wheels of heavy vehicles.

The cost is equivalent to £1,788, about $8,900 per English mile.

RIVER PROTECTION AT PLATTSMOUTH, NEB.*

By THOMAS DOANE, C. E.

The easterly terminus of the Burlington & Missouri River Rail Road in Nebraska is at Plattsmouth on the westerly bank of the Missouri River.

The city of Plattsmouth lies upon and among the bluffs of this river about two miles below the mouth of the Nebraska, or Great Platte River.

This river descends from the west, with a fall of from three to five feet per mile, and discharges the Rocky Mountain waters into the Missouri River, through several mouths. These mouths are very changeable as to location and capacity, and the river is apparently very whimsical as to the particular mouth or mouths which at different times and occasions it selects through which to discharge itself. Its waters are white and at times strikingly in contrast with those of the Great Muddy, and the two waters can be traced for miles before becoming so mixed as to lose their identity.

Freshet time of the Platte River is usually in April, while that of the Missouri, whose sources are much further north in the Rocky Mountains, is in June. If the Platte River in freshet, finds the Missouri at a low stop, it projects its waters entirely across the Missouri; while in cases of local freshets, in which either river may obtain the ascendency, the current takes other courses, and as a consequence keeps the Missouri channels, sand bars, and banks in a very unsettled and unsatisfactory condition for miles below the Plattsmouth.

The station grounds of the rail road lie along the river under the bluffs, between the city of Plattsmouth and the river.

Within ten or twelve years there was a broad meadow bottom extending along in front of the city, having a width from the bluffs of nearly half a mile, but an important change in the Missouri itself, combined with the action of the Platte, has taken this all away, and the river was only restrained by the harder material of which the bluffs are made up.

The Missouri at this point is now from a mile to a mile and a half wide, while the Platte for two hundred miles above its mouth is from half a mile to a mile wide. In consequence of this washing away of the table lands, and the very crooked condition in which the banks were left, it was found that suitable grounds for the rail road could not be had without reclaiming something from the river, or at least substantially protecting what remained.

The problem was, *how to do it*. The conditions were a ledge of rock in the bluff about two miles *below* the station, a *river* in front having a depth at low water of twenty feet, a current of *four to five miles per hour*, running *straight* against the bank to be protected, and carrying

* A paper read before the Boston Society of Civil Engineers, March 15th, 1876.

¼ inch of *sand* in a *tumbler full* of its water, equal to one of sand to twelve of water while in freshet.

It was determined to push out boldly into the river, in order both to reach the *hard bottom* of the *river*, and so save being undermined, and to *secure* an even width of grounds between the river and the bluffs, thus accomodating several parallel rail-road tracks. The line desired was first laid out and soundings were taken along it, giving an extreme depth of twenty feet without material variation. A part of the line was a regular curve, and a part straight.

A steamboat and a couple of 120-ton barges were bought. Upon the boat a pile-driving machine was set up, and along the located line piles were driven at a distance of ninety feet apart, this being the length of the straight sides of the barges. The quarry men were then set at work and large loads of stone were towed from the quarry to the place where the piles were driven. The barges were moored to the piles and the stone were discharged into the water. This was repeated till the stone just appeared at the surface of the water. The piles were all numbered and a record of stone discharged between two adjoining piles was kept, through the whole length of the work. Every other space between the piles was omitted in discharging stone, that is only one half the spaces, and consequently only one half the whole length was filled with stone. The numbering of the piles was necessary, not only to determine the amount of stone put in between any two piles, but to ensure the moving out of stone in the spaces not to be filled.

All this work was done in the spring, and before the occurrence of the June freshet in the Missouri.

It was expected that the heavy current of the river would be restrained by the winrows of stone lying along in line, and that the water running inside between the stone and the banks of the river, would be so retarded as to deposit a considerable portion of their load of sand. The freshet of course overtopped the stone which only reached up to low water level, and so continually provided other waters to dump their new loads of sand. So the work went on perpetually day and night, seven days in the week. After a month or two the freshet subsided, and the whole space *behind the stone*, and up to a *level* with the top of the stones, and also out to a slope in the intervals, even with outer slopes of the winrows, and among the stone too, was found well and honestly puddled full and tight with sand. The common freshet-height of the Platte River is but about four feet, and it rarely overtops its banks, the great fall in the river making it impossible. That of the Missouri River is about ten feet, while its great freshets reach twenty feet.

Having accomplished so much by the help of the boat and the river it now became necessary to abandon the boats and barges which could not work in freshet times and which could not well elevate stone above low water level. A rail road track was now laid upon the sand, and a narrow embankment was raised up to near high water of common freshets. The outside of this was then covered three or four feet thick with stone, having the outer face on the same slope with the stone before discharged into the water, and wherever the slopes in the intervals between the original winrows would take stone they were covered so as to make a uniform face upon the river side. The work was then subjected to another freshet, and all was then filled behind the stone up to its top with river sand.

The economies of this process are the following: While an attempt to fill into the river with earth and then to face with stone would have been entirely unsuccessful, because the earth would be carried away as fast as put in, this process secured the whole of the filling without cost except of time, and of this only about fifteen months.

If an embankment of stone had first been raised to high water mark, the depth at low water being twenty feet, and freshet height ten feet more, with slopes of one and a half to one, there would have been consumed fifty cubic yards of stone per linear foot. By this process the *maximum* quantity of stone used was but twenty-four cubic yards per linear foot. And by filling with stone for only one-half of the total length, the *average quantity* of stone used was but twelve cubic yards per linear foot.

The natural banks of a river, having a height of thirty feet from the bottom,

may be rip-rapped seven feet thick with about eight cubic yards of stone per linear foot, which is a saving of but one-third of the above. The advantages of the process which has been described, over the rip-rapping process, are that land can be reclaimed from the river by the first process, while it cannot under the second.

That the meanderings of the river bank, giving increased length to rip rap, can be reduced to such shapes and lines as may be desired for convenient and economical use.

That the work thus becomes permanent, because much less liable to undermine, and much more sightly because irregularity is reduced to regular curves and to straight lines.

In doing the work above described, it became necessary of course to join the winrows of stone at the upper end to the river bank, in order to prevent a draught of water down behind the stone, for then there would have been no depositing of sand. It is very possible that longer intervals between the winrows of stone might have been left, especially in that part which was straight. To fill every third space would probably have been sufficient in that case.

The distance filled in this case had a length of about half a mile, and a width of from twenty to one hundred feet. The upper half of the length was on a two-degree curve about, and the lower part was straight. It was intended to make a future extension by going further into the river, and around a heavy concave bend in the river, and the lines were laid with reference to this. It is not uncommon to call in the aid of such a river to fill behind stone embankments previously made, but it is not known that intervals have been left in the stone embankments whereby as good work is secured at a great saving of cost.

To calculate how fast such work can be filled with sand, when the river runs five miles an hour, and a tumbler full of surface water carries one-quarter inch of sand, would be a difficult problem to solve, but when such water so laden, loses a portion of its velocity, the filling goes on with remarkable rapidity.

MIXING OF CAST IRON—AND ITS APPLICATION TO FOUNDRY PURPOSES.*

By Mr. T. D. WILSON.

From "Iron."

Foundry or gray iron is denoted as Nos. 1, 2, 3, and 4. A pig of No. 1 when fractured is known by its dark, blue-gray color, and coarse grain; the crystals are large, and extend over the whole surface of the fractured part. It usually breaks even, showing very little tenacity. In its fluid state it is of light color; as it flows from the cupola into the receptacle there is a marked absence of sparks or splashes. The surface is dead and sluggish, and as it cools it becomes covered with a thick scum or *kish*, which is a source of much waste. This iron is seldom used alone; it requires to be remelted, or mixed with a large percentage of scrap for ordinary purposes. When melted to intense heat in crucibles it is much used for small art castings, and for such it is well suited, owing to its particular softness; but in all cases it must be run into the mould very quickly, as the kish, being much lighter than the iron, rises to the surface of the mould, and gives an unsightly appearance to the casting. Art castings made from this iron possess a great amount of flexibility and elasticity, and are filed or chipped with ease. No. 2 is slightly harder than No. 1; is light in color, finer grained, the crystals smaller at the margin of the fracture, and more uneven on the surface. When fluid its color is a bright reddish white; as it flows from the cupola there is a little splashing. It has a sluggish appearance,

* A paper read at the Cleveland Iron Trade Foremen's Association.

and is also "kishey," but not to the extent of No. 1. When being run into the mould it breaks over the edge of the ladle in large sheets, which leave behind them long narrow fissures or lines from side to side of the ladle; but as the iron cools these lines may be observed to open in various directions until the surface is in a brisk, lively motion, the lines intersecting each other until there is a host of figures, which are difficult to explain, but to uninitiated eyes it has a very pleasing effect. This activity continues until the surface becomes stiff or pasty; but on removing this pasty covering these lively figures are again seen flitting about with more action than ever. This metal is also very much used for art castings, but for large castings it is of no use, being too soft and wanting in density. No 3 iron when fractured shows a slightly mottled appearance at the margin, but within there is a regular arrangement of smaller crystals, more compact and dense; when fluid, and as it flows into the ladles, there is a display of sparks flying in various directions, and if melted there is an entire absence of kish or graphite, it possessing a clean mottled surface. As it cools the lively figures are again visible, but much smaller, and pass off altogether as the iron cools. This iron is particularly well adapted for engine or machine castings, if not too massive; it is easily turned or planed, and yet possesses an amount of density which fits it for such work. No. 3 cast iron is the general favorite for foundry purposes; not that it is best for all applications, but that it can be applied to most purposes, owing to its being a medium betwixt the extremes, and can be used in a very great variety of castings. Where large quantities of scrap are available, many advantages can be gained by the liberal use of No. 3 in conjunction with soft pig-iron. Scrap is superior to pig-iron, as it possesses the advantage of having been remelted. He had it on very good authority that cast iron was improved by remelting it up to twelve times. Scrap is melted with less fuel, as it is void of the coat of sand which usually accompanies pig-iron, and more can be melted in a given time, the sand requiring a liberal use of limestone or some other commodity as a flux, and by using an excessive quantity they unnecessarily damage the lining of the cupola. Some time ago he had the opportunity of testing these advantages, assisted by Mr. Oubridge, and the conclusion they came to was, that in using pig-iron delivered directly from the blast-furnace and that obtained from old stocks, there was an average difference of melting of 10 cwts. in the hour in a cupola which was melting at the average rate of 70 cwts. per hour, with a saving of half to three-fourths of a cwt. of coke to the ton of metal in favor of the stock metal; and similar results have been obtained repeatedly by the use of large quantities of scrap with the softer brands of pig-iron. No. 4, or "foundry four" as it is designated (the latter term defining it from "forge four," which is a widely different iron), when fractured, is more or less mottled, has a white glossy appearance; the fracture is usually uneven, showing a large amount of tenacity, which is proved further by being more difficult to break. When melted to an intense heat it has a clean metallic surface, and as it flows into the receptacles it scintillates, the sparks flying in all directions, breaking into small particles, and continuing to fuse during their flight. This phenomenon is visible only in mottled or white iron, unless it be an iron which has been much exposed, such as old scrap, oxydized by the action of the air. Another peculiarity which No. 4 possesses when melted is that there is a constant rising to the surface of small globules or dark flakes, which gradually expand in diameter, and by degrees resume the hue of the molten surface, but are again and again replaced by others, this continuing while the iron is fluid; but as it cools the surface is covered with thin scales, the oxygen of the air combining with the iron, forming oxyd of iron. This iron is well adapted for bulky castings, such as heavy spur wheels, girders, engine beams or similar castings where there is not a great deal of fitting or machine work required. Large locomotive cylinders are about the only exception of engine work, where a great amount of fitting is required, for which this iron is used; for such it is well adapted, owing to its strength and the perfect smooth surface which can be produced upon it, this making it valuable alike for standing friction and shocks,

which such cylinders are subject to. For light castings it is not so applicable, owing to its hardness and its liability to become stiff or pasty while fluid, on being exposed to the action of the air. Speaking of the difference in duration of castings which have the same amount of work to perform, are made from the same patterns, and are in every way similar, he said it was largely due to an utter disregard as to the class of metal used for various kinds of castings; and gave his experience of spur wheels, which proved to be more durable when made of a moderately dense metal. For three years he had not been troubled with any broken wheels, but had taken several out, which were so well worn as to become dangerous for further use. For chilled castings there should at all times be great care and judgment displayed, as to the nature of the castings, the amount of chill required, and the class of metal used. There are a great variety of chilled castings made which differ widely as to the class of work they have to perform, ploughshares requiring chilling on one side only, the surface which comes in contact with the soil, and if chilled too deep they become brittle. These being comparatively light castings, it was essential to use soft iron; that manufactured from spathic ore is peculiarly adapted for chilled castings owing to its containing a large percentage of manganese. Chilled car-wheels, such as are extensively used in America and on the Continental railways, require to be chilled on the outer circumference of the thread of the wheel; but in America charcoal iron melted with cold-blast is at all times preferable, as it chills much deeper than other iron. The State railways of Hungary and Austria use these wheels largely. They are of various designs, though each embody the principal feature—that of curved discs. The total exclusion of wheels of this design in a district like Cleveland is remarkable, seeing such good results obtained from their use in other places, though under different circumstances. His opinion was that their use would be advantageous if applied to slag bogies or metal bogies, as they have the advantage of possessing more elasticity than any other design of cast-iron wheels. It is the rapid solidification of the iron while in a molten state which gives the best results of chilled castings; but in some castings there is a danger of having them too much chilled, as in the case of ploughshares. It is then necessary to heat the parts of the mould before pouring in the metal. In massive articles, such as plate rolls or similar castings which require a very deep chill, the opposite course must be followed. There must be a very carefully selected metal, which should be mottled, or if of a softer kind there must be a proportionate quantity of white, which must be regulated according to the bulk of the castings. The mould which is to receive it should be not less than ten inches in thickness for an eighteen-inch or twenty-inch roll. When the iron is properly mixed it will be utterly useless unless the mould is such as will take up a large portion of the heat, or solidify the surfaces which at once come into contact with it. This is materially assisted by having the molten metal partially cooled before pouring into the mould. Osborn, writing on this subject, says "that when gray cast iron is heated far above its melting point and poured into a mould made of a bad conductor of heat, the fractured surface presents no great difference in appearance, but the internal part contains more graphite carbon than the external, and so in chilled castings." This is visible on the fracture of any large castings, either chilled or sand. It is caused by the center of such castings being cooled much lower than the external surface, and if such be made from a highly carbonaceous iron, cast in a loam mould and coated with foundry blacking, which is highly refractory, being almost a pure carbon, the difference would be more striking, the internal parts would appear much softer, contain a large amount of uncombined carbon, which by the blow of a hammer could be separated from the bulk of the metal in small metallic flakes, which when pressed betwixt the finger and thumb present to all appearances particles of black lead, while the external surface of the fracture would be slightly denser than the pig which formed the charge. Thus, to use a soft carbonaceous iron for large castings is to use the weakest. The free carbon can only be reduced by repeated re-meltings, which increases the chemically-mixed or

combined carbon, and at the same time increases the strength of the metal. His opinion respecting the casting of rolls was that if they were cast hollow, by having a core of, say, two inches or two and a half inches diameter in the center, and impinging a blast of cold air into the center core, the lines of crystallization would be so changed by the combination of the free carbon with the iron, that the result would be much stronger than when solid. The specifications which usually accompany orders for cast iron generally contain a clause respecting the tests of the metal to be supplied in the form of castings. Usually the test that is required approaches the maximum strength of cast-iron, and as the castings required are in some cases of very light section it is essential that a soft and ductile iron should be used to insure a perfectly smooth and sound casting, while test bars cast from the same iron would fail to stand anything like the test of 30 cwt., owing to its softness; but in using a class of iron which would be close and strong, and in every way suitable to give good results in testing, it would be utterly useless for castings of light sections, and if it were melted fluid enough to run such a casting it would not be a strong article, but very brittle. Malleable castings are continually in growing demand, as the application of the process to secure those irregular-shaped articles which would be very costly if forged, and practically useless if made from ordinary cast iron, such as small castings connected with the structure of sewing-machines, small screw-keys, spur-wheels, castings connected with steam-ploughs and a very great variety of others for machine and other purposes where strength and malleability are required. The cast iron used for this purpose is not of the ordinary marketable iron, but is manufactured from red hematite ore melted in cold-blast furnaces with charcoal. The process is that of cementation; after the castings are well cleaned they are embedded in powdered red hematite or iron scales—black oxyd—which is to be had about the forge anvils, and then subjected to a red heat for a length of time, varying according to the substance of the article. The result is a very malleable iron.

In answer to a question by the chairman as to what proportion there would be between the strength of rolls when treated in the manner he had advocated and in the ordinary way, Mr. Wilson explained a drawing he had made, showing the usual appearance of a twenty-inch roll when cooled, as compared with the appearance of a roll cast with a hole in the center. In the former case the iron presented density to only one-third of its thickness, and the iron was weaker in its center. His idea was that by using a hole they would get greater density, and consequently greater strength. He had not seen the plan carried out, but he drew his inferences from the fact that gun-barrels were cast hollow. He then explained a diagram showing the car-wheels used in America, in which the strength was mainly due to the shape of the wheel. Numbers of slag bogies were in use, the wheels of which were liable to be overheated by the explosion of slag balls, and this shape of wheel would allow for expansion.

Mr. J. M. Oubridge said his impression was that a two and a half-inch or three-inch hole in the roll was not enough. They could not cast a hole of that size unless they used water, which would be objectionable. He explained how in casting a hydraulic cylinder he used a six-inch hole, the object being to insure crystallization of the iron. By throwing a two-inch pipe through the center of the roll they could supply a blast of air to keep the metal cool; but by making the hole one-third the diameter of the roll they would cast it of double strength. It was perfectly impossible to use water in such small holes because of the danger of explosion, but it might be done by using air. On the question of test bars he thought there was nothing which founders ought to set their faces more against, for in many cases the test bar was perfectly useless. To get a test of twenty-eight they must use an iron of very close texture, and in a large casting they did not get the same amount of strength. The only value of a test bar was to know the relative value of the iron they were mixing, and it must be left very much to the judgment and skill of the foremen. He thought that engineers had lost their way; for if, instead of getting men to watch the test-

bar system, they would try to learn the relative value of iron, it would be a great advantage to themselves and the trade at large. Referring to the car wheels, he said that the Americans had found that the greatest effect was obtained from seven different mixings of iron, and they had a method of tempering down their wheels to stand the hard winters which they had to undergo. English wheels were of no use there, but must be tempered sufficiently to stand the severe frost. He believed he was correct in saying that the American car wheels were reckoned to have a life of between 40,000 and 50,000 miles. Recurring to the test bars, he said that he found on taking a bar two inches square, another one inch square and another three-quarter inch, the two-inch bar was only two-thirds the relative value of the three-quarter inch one; and if they took a two-inch bar and planed it down to one inch they removed the strongest part of the iron.

Mr. Wilson, replying to this, remarked that by using a very soft brand they would get a very good test bar, but by using denser iron they got the best relative value from the bar.

Mr. Chatto defended the engineers, in reply to Mr. Oubridge, and contended that they might have the credit of knowing that a two-inch bar was not so strong as a three-quarter inch one. He thought there was a great deal of roguery carried on in the test-bar system, especially among moulders.

Mr. Oubridge said it was his misfortune once to have to make some very thin castings, and although the test bar was good the castings were perfectly brittle.

Mr. Miln said he had seen numbers of wheels cast in West Canada which had to be thrown away because they were not sufficiently strong to stand the weather.

Mr. Wilson, in reply to a question by Mr. Miln, said that if anything was taken away from a wheel it should be from the inside. This class of goods should be made from a well-selected class of iron. Cleveland iron was good for anything of this kind, but it must be cast under pressure. If a cylinder broke from overwork it was too weak, but if it wore away it was too soft. In some of the cylinders running on the Stockton and Darlington line they would be surprised to see how they had been tooled and planed.

Another gentleman said his experience of locomotive cylinders was, that the time spent in tooling and planing was not lost time, provided the iron would stand it.

Mr. Wilson said that Mr. Oubridge was the first to recommend that the iron used in locomotive cylinders should be selected from what was in store, melted in a cupola, run out and cast in galleys two and a-half inches or three inches deep, and the result of that practice had been very satisfactory. In every case for the last three years they found they got good cylinders with the best results.

ANGULAR CROSS-SECTIONING.

By F. Z. SCHELLENBERG, C. E.

Written for VAN NOSTRAND'S ENGINEERING MAGAZINE.

A most direct and expeditious method to get differences in level between points in sight is by the use of a vertical arc graduated to the successive sines 1. 2. 3. . . . . 100, in the quadrant, for the radius of arc 100.

Multiplying the distance measured in hundreds on the slope by the rate per hundred indicated on the arc gives the difference in level in units. In the higher parts of the arc the corresponding cosines may be marked for deriving horizontal distances.

The applicability of this graduation to such purposes, as described under this caption by R. Bell, C. E., in May number, is obvious as may also be its use for more extended profiles, for geological cross-sections, for road grading, or wherever between points obtained by the leveling instrument its accuracy is not indispensable.

A clinometer thus graduated enables contour lines for topographical work to be most readily determined. The table following gives the one hundred points in the quadrant in terms of the common graduation of 90° to the quadrant.

Vertical Distance for 100 Measured on Slope.	Horizontal Distance for 100 Measured on Slope.	Angle with Horizon.	Vertical Distance for 100 Measured on Slope.	Horizontal Distance for 100 Measured on Slope.	Angle with Horizon.
0		00° 00′	51		30° 40′
1		0° 34′	52		31° 20′
2		1° 09′	53		32° 00′
3		1° 43′	54		32° 41′
4		2° 18′	55	83.5	33° 22′
5	99.9	2° 52′	56		34° 03′
6		3° 26′	57		34° 45′
7		4° 01′	58		35° 27′
8		4° 35′	59		36° 09′
9		5° 10′	60	80.0	36° 52′
10	99.5	5° 44′	61		37° 35′
11		6° 19′	62		38° 19′
12		6° 54′	63		39° 03′
13		7° 28′	64		39° 48′
14		8° 03′	65	76.0	40° 32′
15	98.9	8° 38′	66		41° 18′
16		9° 12′	67		42° 04′
17		9° 47′	68		42° 51′
18		10° 22′	69		43° 38′
19		10° 57′	70	71.4	44° 26′
20	98.0	11° 32′	71		45° 14′
21		12° 07′	72		46° 03′
22		12° 43′	73		46° 53′
23		13° 18′	74		47° 44′
24		13° 53′	75	66.2	48° 35′
25	96.8	14° 29′	76		49° 28′
26		15° 04′	77		50° 21′
27		15° 40′	78		51° 16′
28		16° 16′	79		52° 11′
29		16° 51′	80	60.0	53° 08′
30	95.4	17° 27′	81		54° 06′
31		18° 04′	82		55° 05′
32		18° 40′	83		56° 06′
33		19° 16′	84		57° 08′
34		19° 53′	85	52.7	58° 13′
35	93.7	20° 29′	86		59° 19′
36		21° 06′	87		60° 28′
37		21° 43′	88		61° 39′
38		22° 20′	89		62° 52′
39		22° 57′	90	43.6	64° 09′
40	91.6	23° 35′	91		65° 30′
41		24° 12′	92		66° 56′
42		24° 50′	93		68° 26′
43		25° 28′	94		70° 03′
44		26° 06′	95	31.2	71° 48′
45	89.3	26° 45′	96		73° 44′
46		27° 23′	97		75° 56′
47		28° 02′	98		78° 31′
48		28° 41′	99		81° 54′
49		29° 20′	100	0.0	90° 00′
50	86.6	30° 00′			

THE Belgian minister of public works has given out an order for fifty locomotives on the express condition that no foreign materials are to be used in the construction of the engines. The order has been divided between M. Carels, of Gand, the Belgian Construction Co., the Haine St. Pierre Co., the St. Leonard Co., and the Belgian Colliery and Metallurgical Co.

THE STRENGTH OF RAIL JOINTS.*

By Mr. C. P. SANDBERG, of Westminster.

The introduction of the plain fish plates now ordinarily used was a great advantage at the time to the railway world, mainly for preventing accidents by keeping the rails in position laterally, but since speed has increased, and weight of engines also, the plain fish plates have been found deficient in one vital respect, viz., that of giving the rail joint the same stiffness and elasticity as the solid rail, so as to obtain one continuous road.

As the stiffness of the joint with plain fish plates principally depends upon the section of the rail, and the fishing angle, often only a third of the stiffness of the joint is afforded as compared with that of the solid rail, but even in the best cases, scarcely more than half the rail stiffness is obtained (see experiments Nos. 1 to 6). The result is a broken road, early failure of the rail-ends, and broken tyres and springs. Iron rails particularly are exposed to destruction at the ends before they are half worn out at the middle, and have to be taken up, cut down, and relaid. Even steel rails, although experience has not gone so far yet on a large scale to prove it, will ultimately fail first at the ends with the ordinary mode of fishing.

This was particularly the case when the joint was on a sleeper with the base plate to hammer on, which led to the use of the suspended joint to obtain a smoother run. Nevertheless, it is found already by experience that one continuous line is not obtained by this simple remedy, inasmuch as the sleepers are sunk down in the ballast wherever there is a weak part of the iron super-structure, and the result is that there are two sleepers to lift up at the joint instead of one. As said before, it was a bad plan to strengthen the joint by taking away the sleeper from under it. Were the sleepers on the road as fixed as the supports in a testing machine, it might have done, but as they are not, there is no gain whatever except what 2 feet center of supports offers over 3 feet center, as the former leaves 18 inches clear space only sufficient for stopping.

The introduction of steel rails necessitating the abolition of notches in the rail flange as destructive to the strength of the rail, has led to the design of the French or German fish plates (éclisse arret) adapted for suspended joints, but requiring base plates at the joint sleepers (see *Engineering*, March 20, 1874). Even with this plan the experiments show only two-thirds of the strength of the solid rail is obtained, and as only one fish-plate of this description is generally used, there is still less stiffness. Several other plans exist, more or less complicated, but as none have yet given the same stiffness as the rail, combined with cheapness in cost and maintenance, they have not come into general use, and the weak joint with ordinary plain fish plates, is still generally adopted.

This has given rise to the foregoing experiments and design of the deep fish plate for flange rails, similar to what has been already adopted for double-headed rail sections on many English railways.

With a rail section having a wide flange, this deep fish plate is of course more difficult to roll than for the double headed rail section, and also than the éclisse arret; but as there is no complication in design, and only ordinary punching required, doing away with base plates, and notching the rail flanges, it is to be hoped that if proved satisfactory and generally adopted, it might be made and obtained for the same price per weight as the ordinary fish plates.

As to the cost of this improved joint, it would be increased only by the greater weight of the fish plates, and as the ordinary fish plates may be taken to weigh about four per cent. of the rails, these will be, say 8 per cent. of the new fish plates, saving the base plates altogether. It is true that in the smaller sections where bolts with square nuts are used, it might necessitate exchange for hexagonal nuts to make them turn, which are somewhat dearer than the square ones, but this is partially compensated by the saving in weight, as the hexagonal nut weighs less than the square one for the same bolt.

* A paper read before Iron and Steel Institute of Great Britain.

Besides, the introduction of this fish plate on already existing roads might be gradually effected without changing the nuts, where they would not turn round, by using one fish plate of the kind on the bolt-head side of the joint, and a material improvement would be thereby obtained, inasmuch as such joint would possess 80 per cent. of the stiffness of the solid rails, as shown by experiments Nos. 10 to 18. As regards the use of two deep fish plates, the experiments are conclusive as to the great increase in stiffness being even stiffer than the rail (see Nos. 19 to 30, also Nos. 40 and 41) both as regards strength and elasticity, for two different rail sections of which, however, the section with 15° fishing angle is preferable, as the bolt is not likely to work loose.

The plan of punching proposed, and the distance apart of joint sleepers, is shown on the drawing, being that ordinarily used for flange rails, on which it is seen that the deep stem of the fish plates abuts against the sleepers, and prevents the road from traveling without notching the rail flange, but of course, a greater distance between the joint sleepers might be used to compensate for the extra ten per cent. of stiffness beyond that of the rail if necessary for stopping.

As for strength, experiments No. 4 and No. 30, both on 2 feet supports, show a load of 35 tons with more deflection on the rail than on the joint, proving a slight superiority of the joint, even in this respect best shown by the fact that the bolts were not the least hurt after such an extremely heavy test. The fish plates might be made of either steel or iron, but in the former case they should be punched hot, or well annealed after punching cold.

The small extra cost of this improved fish joint, judging from the results of these experiments, will be recovered over and over again by less cost of maintenance of permanent way, longer duration of the rails, particularly iron, and less wear of rolling stock, as well as greater comfort to travelers by obtaining one continuous line.

It would also involve another vital improvement, viz., the prevention of breakage of the rails through the bolt holes even when punched. No doubt this is caused by the weakness of the present fish joint, causing it to sink down under

EXPERIMENTS ON STRENGTH OF RAIL JOINTS.

Description of Rail and Rail Joints.	Experiment. No.	Distance of Supports. Feet.	Load in Tons Dead Weight.	Deflection in Millimetres. Tempy.	Permt.
SOLID IRON RAIL.	1	3	16	2	0
67 lbs. per yard Flange. Section 4⅞	2	"	18	3	0
in. high by 4¼ in. broad, 15° Fishing	3	"	20	4	1
Angle.	4	2	35	5	3
SAME RAIL SECTION.					
Ordinary Fish Joint. Fish Plates 18	5	2	9	2	0
in. long, ⅞ in. thick.	6	"	11	3	1
SAME RAIL SECTION.					
Fish Joint, French Pattern. Fish	7	2	12	2	0
Plates 18 in. long, ¾ in. thick, used	8	"	15	3	1
with base plate suspended Joint.	9	"	20	3	1
SAME RAIL SECTION.	10	2	10	1	0
	11	"	11	2	0
Fish Joint with ordinary Fish Plate	12	"	12	2	0
on one side, deep Fish Plate on	13	"	13	2	0
other side. Both 18 in. long. Deep	14	"	14	2	0
Fish Plate ⅝ in. thick at the top, ½	15	"	16	3	1
in. thick at the bottom. Deep	16	"	18	3	1
Flange 3 in. below Rail Flange.	17	"	20	4	1
	18	"	22	5	1

Description of Rail and Rail Joints.	Experiment. No.	Distance of Supports. Feet.	Load in Tons Dead Weight.	Deflection in Millimetres. Tempy.	Permt.
SAME RAIL SECTION.	19	2	12	2	0
	20	"	14	2	0
Fish Joint with two deep Fish Plates	21	"	15	2	0
18 in. long, same as above.	22	"	16	2	0
	23	"	17	2	0
	24	"	18	2	0
	25	"	20	3	0
	26	"	20	3	$\frac{1}{2}$
	27	"	22	3	1
	28	"	25	4	1
	29	"	30	4	1
	30	"	35	4	2
SOLID IRON RAIL.					
66 lbs. per yard. Flange Section $4\frac{3}{4}$	31	3	18	3	0
in. high by 4 in. broad in Flange,	32	"	20	5	1
Fishing Angle 30°.					
SAME RAIL SECTION.					
Ordinary Fish Joint 18 in. long, Fish	33	2	8	2	0
Plates $\frac{1}{2}$ in. thick.	34	"	9	3	1
SAME RAIL SECTION.	35	2	11	2	0
	36	"	12	3	1
Fish Joints, French Pattern, Fish	37	"	"	3	1
Plates 18 in. long, $\frac{3}{4}$ in. thick.	38	"	15	3	1
	39	"	20	4	2
SAME RAIL SECTION.					
Fish Joint with two deep Fish Plates	40	2	18	2	0
18 in. long, $\frac{3}{4}$ in. thick at the top, $\frac{1}{4}$	41	"	20	3	0
inch thick at the bottom.					
SOLID IRON RAIL.					
56 lbs. per yard, $4\frac{1}{4}$ in. high by 4 in.	42	3	14	2	0
broad in the Flange, Fishing Angle,	43	"	16	3	1
15°.					
SAME RAIL SECTION.					
Ordinary Fish Joint. Fish Plates 18	44	2	6	2	0
in. long, $\frac{3}{4}$ in. thick.	45	"	7	3	1
SAME RAIL SECTION.	46	2	11	2	0
Single deep Fish Joint.	47	"	13	3	1
SAME RAIL SECTION.	48	2	16	2	0
	49	"	18	3	1
Double deep Fish Joint.	50	"	20	4	2

the engine, resulting in a blow from the bolts to the upper part of the holes in the rail. Such would not be the case with these stiff fish plates, and the drilling of the bolt holes which is now so often insisted upon, particularly for steel rails, to the great cost and inconvenience to the maker, might then be done away with.

It is to be hoped that practical experience will bear out the result of these trials; at any rate, it will not be long before results on the road, whether good or bad, will be obtained, for some of these deep fish plates are already made, and will have a fair trial on one of the best Government Railways in Europe.

Meanwhile any information on the subject would be most thankfully received, and it should be distinctly understood that the author has no pecuniary interest whatever in the introduction of this deep fish plate, but only wishes for the best pattern so as not to be blamed for the short duration of the rails through supposed faults in the manufacture or inspection, when the ordinary fish joint is the real cause, and is also the weak point in the construction of the permanent way.

ON THE USE OF THE GRAMME MAGNETO-ELECTRIC MACHINES FOR LIGHTING RAILROAD DEPOTS.

Translated from Comptes Rendus, by THEO. F. KOEZLY, M. E.

In a recent communication to the Academy, M. Tresca has given an account of a series of experiments, which he had instituted for the purpose of determining the work performed by the magneto-electric machines of M. Gramme, used to produce light by electricity. His experiments had reference to two machines emitting light equivalent in brilliancy to 1,850 and 300 (carcel) candles respectively.

Authorized by the "Compagnie du Nord" to make a series of similar experiments with the aid of MM. Sartigue and Rouderon, standard machines of 50, 100, and 150 candle power, respectively, were selected for the purpose.

Repeated experiments have been made in the freight depot having an area of 1,500 square meters (16,146 sq. ft.), and a capacity of about 19,000 cubic meters (671,023 cub. ft.), as well as in the large market whose area is 11,000 square meters (118,404 sq. ft.), and 300,000 cubic meters (10,595,100 cub. ft.) in volume.

The power necessary to set magneto-electric machines in motion was ascertained by a comparison with engines driven by gas or vapor, of two, three and four horse power, used either separately or coupled. Previous determinations, however, with a Prony dynanometer had given the relative volume of gas consumed to the power derived (*i. e.* useful work) all the conditions remaining the same.

The lamps which were used in the experiment were regulators of the V. Serrin type, and answered the purpose remarkably well.

The following results were obtained :

		Magneto-electric Machine of		
		50 Candle Power.	100 Candle Power.	150 Candle Power.
Number of revolutions of the bobbin per minute		1,650	800	800
Power necessary to secure a steady light	with carbons 0m.007 apart	2ch.*2	2ch.4	2ch.5
	" " 0m.009 "		2ch.6	2ch.7
Consumption of carbons of the lamp including waste.	with carbons 0m.007 apart, at positive pole	"	0m.090	0m.135
	" " 0m.007 apart, at negative "	"	0m.045	
	" " 0m.009 apart, at positive "	"	0m.060	0m.090
	" " 0m.009 apart, at negative "	"	0m.030	

Thus it has been indicated by M. Tresca that these results show that the power necessary to produce a certain amount of electric light, for instance, that equivalent to 100 candles, increases very rapidly in proportion to the diminution of the total quantity of light; whence M. Tresca has proven that the work per 100 candles was only 0.ch415 for a lamp of 1,850 candles, that it was 0.ch920 for 100 candles with a lamp of 300 candles, whilst the work per hundred candles amounts to 1.ch7, 2.ch4, and 4.ch4 for machines of 150, 100, and 50 candles respectively, with the carbon points seven millimeters apart.

The experiments have furthermore shown that the requisite power to obtain the formation of the Voltaic luminous arc is about ten per cent. greater than that which burns at the uniform rate. This is true at the starting of the machine when the carbon points are in close contact and the resistance to the passage of the current only feeble; when, by and by, the electricity developed is transformed into magnetism in the electro-magnet and revolving band of the Gramme machine, and these then act

* Ch. or Force de Cheval = 0.9876 H. P.

successively, in forming a kind of brake which continually charges the motor.

The experiments have shown that the power given out by magneto-electric machines varies with the sizes of the carbons of the lamp, a little more power being requisite for $0^{m}.009$ than for $0^{m}.007$ carbons. This again is due to the smaller resistance offered by the $0^{m}.007$ carbons to the passage of the electric current, producing the effects of a brake as mentioned above.

En résumé, the power varies but little in machines of 50, 100, and 150 candle power, and, consequently, the rates of production of all the light from these different machines are sufficiently close. Excluding exceptionally rare cases, it will be advantageous to employ machines of 100 and 150 candle-power.

It has been seen that the consumption of the carbons of the electric lamp was $0^{m}.135$ and $0^{m}.090$, when the carbons were used at distances of $0^{m}.007$ and $0^{m}.009$ apart. From this time forward the "Compagnie du Nord" is warranted in paying for carbons of coke, and even for those of M. Carré, which are perfectly regular, at the rate of one franc per current meter; whence the figure, representing the cost per hour, may be set down at $0^{fr}.135$ and $0^{fr}.090$.

The following figures are interesting, in so far as they give the comparative expenses incurred in the use of electricity and gas as means of illumination. Taking, for example, the lamp of 150 candles and allowing it to emit light for ten consecutive hours in some large spacious halls or railroad depot, 150 carcel candles will require a consumption of $150 \times 0^{mc}.105$ of gas per hour, equal to $15^{m}.75$, which, at the rate of $0^{fr}.36$ per cubic meter would constitute an expense of $5^{fr}.70$.

In using electricity for illumination, 150 carcel candles require $2^{ch}.7$, which, at the rate of $0^{fr}.09$ per horse-power per hour (including cleaning and lubrication) the expense would amount to $0^{fr}.24$; adding to this, $0^{fr}.09$ for the carbons of the lamp, $0^{fr}.45$ for wages to the employé, and $0^{fr}.20$ for the interest and liquidation of the expense of instalment, the total amount would be $0^{fr}.98$, or, in other words, between the one-fiftieth and one-sixtieth part of the expense involved when using gas for illumination.

As an electric light of 150 carcel candles lights up advantageously a circle of about forty-five to fifty meters in diameter, it is evident that illumination by electricity, being so much superior in intensity, it ought to be more economical than by using gas, since the illumination of the *same area* requires the light of more than twenty-five gas jets consuming 105 litres per hour.

From the experiments carried on in the freight depot, it was ascertained that the building could be improved by having a single lamp in the center, and at a considerable height, but at the same time, it has been observed that the shadows cast could often be a serious objection, thus necessitating, in many cases, the use of at least two lamps, to diminish the shadows of the one by the light of the other.

Moreover in order to avoid the dazzling glare produced by the light directly, the voltaic arc, after many trials, has been enclosed in a globe of crown glass, $0^{m}.10$ in diameter, the lower half being left unpolished; in order not to lose the rays passing through the upper half of the globe, a parabolic reflector constructed by M. Luchaire was so adjusted as to bring the center of the voltaic axis in the focus. With this arrangement, or simply with the addition of a large reflector of white paper behind the lamp, when this is placed against the wall, it has proven successful, while experimenting at the railway terminus of the North, to produce penumbrae, whose presence is the indication of the better conditions which may be expected from illuminations of this kind.

A CONTEMPORARY informs us that Dr. Heeren recommends the following plan for giving to iron wire a silvery appearance. The wire is prepared by immersion in sulphuric acid, in which a piece of zinc is suspended. The wire is then placed in contact with a plate of zinc in a solution of two parts tartaric acid in 100 water, to which three parts chloride of tin and three parts soda are added. The wire remains a couple of hours in the bath, and is surfaced by polishing or passing through a draw-plate. Spiral wire, or any fashioned iron, can be surfaced according to this plan.

ON THE CASSON-DORMOY PUDDLING FURNACE.

By Mr. E. FISHER SMITH.

Journal of the Iron and Steel Institute.

It is generally confessed that, up to within the last few years, but comparatively little attention was directed in Great Britain to economizing fuel. With a low price of coal and dear labor, it is no doubt, in many cases, perhaps more economical to work with the simplest possible apparatus. These conditions were much altered by the great rise in the prices of fuel and raw materials consequent on the sudden revival of trade after the last great war. It may well be doubted whether materials will ever again fall to their old prices, especially as the selling price of finished iron is now out of all proportion low in comparison. Any furnace, therefore, inexpensive to erect, and which can show a clear saving in cost of working, without any fall in quality of produce, must necessarily commend itself to the attention of this Institute as representing the iron trade of the country.

Such a furnace, it is believed, we have in that now commonly known as the Casson-Dormoy furnace. It has been attempted, in its construction, to perfect the main features of the old reverberatory puddling furnace of Cort, and to thereby intensify and concentrate its action and diminish its working expenses. At the Round Oak Iron Works, this system of furnace has been tried between three and four years, and three such furnaces have, during the last five months, been producing ninety tons of iron weekly, consuming about sixteen cwt. of screened slack per ton; whereas thirty cwt. per ton is usually consumed by the old method; saving about two-thirds in fettling, and from 1s. to 1s. 6d. per ton in bricks and castings. At the same time, the quality of the iron is found to be superior to that made in the ordinary furnaces. This can be seen from the samples exhibited, which were rolled direct from the puddled bars from pigs of the lowest mixture used at Round Oak. Three similar furnaces at the Tudhoe Iron Works, Spennymoor, have produced even better results; the output being greater, and the average consumption of coal per ton for the year being only twelve cwt. The Wigan Forge and Rolling Mills Company, after making their own tests with the furnace, have determined upon laying down the whole of their new forges upon this system in conjunction with the Stoker puddling machine. The Kirkstall Forge and Iron Company, and Messrs. Baldwins, are applying this system of furnace in combination with the Pickles apparatus. At Round Oak, a modification of the Griffith's machine has been adopted for the similar new furnaces now in course of construction. As regards fuel, the most economical method in regular use at the Round Oak Works is to screen the slack, to use the screenings in the Casson-Dormoy puddling furnaces, and to burn the fine siftings or dust by means of mechanical stokers under the firing boilers.

To begin with a brief general description, it is to be observed that this furnace is of the usual reverberatory form. It consists of three chambers. In the first, is the grate, the flames from which pass over the bridge, and are reverberated by the dome upon the bed in the second chamber. The bed consists of a cast basin or dish, resting on a number of iron friction balls, laid in a second pan of wrought iron filled with water, the supply of which is kept up from a jet of about the diameter of a quill. This basin easily adjusts itself on the balls for expansion or contraction, and it may also, when required, be turned about to allow of equal wear and tear.

Through the puddling door on each side of the bed, the two mechanical rabbles are introduced, and worked through a small orifice at the bottom. Both doors are lined with Stourbridge clay, and have the usual hole for slag just below them. The third, or preparatory chamber, forms a kind of second bed or hearth, the pigs are heated here almost to melting point by the waste fire gases on their way to the stack. In working the furnace, on the fire being got up, the pigs are put into the preparatory cham-

ber, and allowed to remain till they are on the point of fusion. They are thereupon passed over the flue bridge into the basin by means of a bar, and are then completely run down by the reverberated fire-gases from the grate. The rabbles, somewhat bent down at the working end, are introduced from the doors, and the puddling commences. Each rabble is either worked by hand through the orifice, or attached to the mechanical puddler. This is of the usual character, consisting of a vertical reciprocating lever which can be connected at will, and driven by a crank and suitable spur gearing, erected on a frame above the dome of the furnace. As soon as the metal becomes pasty and adhesive, the rabbles are withdrawn, and the iron "balled up," and shingled in the usual manner.

The grate is fitted with a cast iron plate, of the full width of the furnace, and sloping upwards to the bridge at an angle of thirty degrees. The back of the grate also slopes to an angle of about thirty degrees, and is constructed of cast iron fire-bars set close together. The bottom is also formed of ordinary round or square bars. Blast is admitted about five inches below the bars on each side, the bottom being kept air-tight, as also the sloping back; this back has a drop door to enable the under-hand occasionally to prick the bars. The area of the grate is only five feet ten inches × one feet ten inches, being somewhat less than that of an ordinary single furnace. The main object of the sloping plate is to prevent any clinkers forming at the back, as the blast of air keeps it cool. The grate is fed in the usual way. The puddling basin rests on a brick pillar about one foot four inches from the ground. On this is first set a wrought iron circular open dish, with sides about four inches deep; within this dish, eight or more friction balls, five inches in diameter, are placed at equal distances from each other. On these spheres, two cast-iron semi-circular plates are laid. On these plates again, four side or segment plates are set, bolted together externally by means of wrought iron pins, and forming a complete circle. Upon these are placed loosely the shelf or table plates, which, resting upon brackets fixed to the rail buck-staves, support the walls of the furnace. All the plates forming the basin are thus free to expand and contract with the variations in the temperature. The dish below being kept full of water, the evaporation produced from the heat above efficiently cools the bottom and sides, and consequently the fettling. The furnace is worked in the following way:—The preparatory chamber, besides heating the pigs, serves as a neck to the whole furnace. As soon as the iron is melted, the rabbles, which are so set that they cannot catch into each other in crossing, are fixed to the machine, and worked at the slow motion for about five minutes. This speed is quickened until the iron boils, when the slower speed is put on till the iron drops. The heating chamber is then charged; this is done with a few pigs at a time, so as to enable the iron to get equally heated all through, one pig is kept to the last, in order to be placed near the bridge, thereby keeping the ends of the others from absolutely melting. The rabbles are then removed, and the real work of the puddler begins by his balling up the iron in the usual manner. The balls, which are of the ordinary size, are drawn from each door, and the cinder tapped. A few shovelfuls of hammer slag and scale are thrown on the bed, and the pigs, which have meanwhile been supplied into the preparatory chamber, are again passed over. These generally melt on the bed in ten minutes or a quarter of an hour. The charges of about nineteen cwt. usually take from an hour and twenty to an hour and forty minutes. Iron shields are fixed on each side of the doors between the two buckstaves, and about one foot from the ground floor. It is found that the heat of the upper portion of the furnace induces a constant circulation of cold air between the casings thus formed, and the surfaces of the brick wall protect the puddler when the door is drawn up to pick out the blooms.

In spite of the important results of this system—results not attained without the usual amount of experimenting—it is not claimed that all the separate features of the furnace present any strongly-marked stamp of originality; the pig or heating chamber has probably been used before, though not, it is believed, worked in the method here adopt-

ed now, in connection with a double furnace, and especially not with mechanical rabbling. The peculiar circular bed or basin is perhaps the most original, while it is also one of the most important characteristics of the furnace. By the absence of inequalities and corners, its shape does away with the difficulties usually attending the working of a mechanical rabble, at the same time effecting a considerable saving in the fettling. Precisely stated, the following are some of the most direct advantages of the circular puddling basin :

1st. This circular form easily enables the rabbling to be worked by machinery, as there are no jambs that the rabbles cannot reach in their regular courses from right to left and back again.

2d. The dimensions, as affected by the working, do not vary to any appreciable extent from day to day ; this is an important point with all furnaces, but especially with furnaces in which the puddling is done by machinery.

3d. The contours being circular, and the sides and bottom of the basin being free, they scarcely ever crack. The only renewals, are of the doors, door frames, and bridge plates.

4th. As the strain of the furnace is almost entirely thrown upon the circular side plates, no external or casing plates are requisite, thus permitting an economical construction of furnace. The buckstaves consist merely of rails or similar bars.

The advantages of a preparatory chamber are : (1) The saving of time in melting down, which, in this case, means a proportionate saving of fuel. (2) The pigs are freed from the siliceous matters derived from the blast furnace pig bed, and adhering to their surfaces. Ordinarily, this sand is well known to be injurious to the bed of the puddling furnace itself, by wasting the fettling and in other ways.

The advantages of the peculiar grate are : (1) The employment therein of blast, which can be regulated so that the furnace is perfectly under control, and the puddler can obtain either an oxydizing or reducing flame at will. (2) The drop doors and sloping back enable the underhand to prick the bars, and thus clean the grate without disturbing the blast below. (3) It permits the use of screened slack instead of forge lumps. (4) The sloping back grate, cooled behind with blast, prevents the formation of clinker.

It would be difficult to exactly determine the indirect or contingent advantages contributed by each separate portion of the furnace, but it may be added that the increased efficiency of the reverberatory furnace has been found, in practice, to have the result of saving about one-half in fuel, fettling, castings, and bricks. Alterations in an old forge, in which to apply this system, can be made without interfering with its current work or its existing plant, whilst considerable space is gained for ventilation or other purposes, inasmuch as five of these furnaces will do the work of fifteen old single ones.

THE NEW YORK DOCK COMMISSION—REPORT OF THE BOARD OF ENGINEERS.

The forthcoming Report to the Commissioners of Docks, is a document of undoubted value to engineers everywhere.

We can present here only such abstracts as fairly set forth the nature of the investigation to which the attention of the appointed Board was specially directed, together with their general conclusions in regard to the plan of the original work.

The present Report opens with the communication of the Commissioners to the Mayor. It includes the following narrative :

The original plan for the construction of the sea-wall, devised by General McClellan, the then Engineer-in-Chief,

is known as the beton block system, which consists of the formation of massive concrete blocks formed in moulds, and manufactured in the open air, in such sizes as the nature of the work demanded. These blocks, when properly hardened, were lowered by the aid of the large floating derrick to a foundation of piles firmly driven, and then sawed off so as to form an even bed. An example of this system of construction is found at the Christopher Street section.

In the month of July, 1873, General Charles K. Graham was appointed Engineer-in-Chief of the Department, in place of General McClellan, who had resigned.

It appears from the records of the Department, that in the month of October, 1874, with a view to more economy in the construction of the sea-wall, the Engineer-in-Chief recommended to the Board, as a substitute for beton blocks, that concrete en masse should be formed upon a foundation of piles in a wet caisson, the concrete being lowered to its place within the caisson (by appropriate machinery), in tilting buckets, and then left to harden in a solid mass. The heads of the piles were not cut off after being driven.

In the month of November following, our predecessors, by formal resolution, adopted the recommendation of General Graham, and ordered the work to proceed, which was done, and about three hundred and forty-seven feet were constructed.

For particulars concerning this system of bulkhead wall construction, see report of General Graham herewith enclosed.

The new Board of Commissioners was organized on the 2d day of May last, and, on the 2d of June following, General Graham resigned the office of Engineer-in-Chief, and, as soon as practicable, his successor, George S. Greene, Jr., was appointed to fill the vacancy.

The attention of Commissioners being called to possible defects in this method of construction, the subject was referred for investigation to the Executive Committee, who directed the Engineer-in-Chief to make a careful examination of the work, and report the result.

The difficulties attending the examination in turbid water, and the results thereof, are explained in the Engineer-in-Chief's report. The examination has proceeded far enough to excite in our minds very grave apprehension as to the safety of that portion of the wall covered by the Report.

If our apprehension should be well founded, we desire to avail ourselves of such remedy as the combined wisdom of the highest authorities may be able to suggest. This is not only due to the great interests of the city, but it seems also just that individuals who may be considered responsible for the work, should have the advantage of the fullest and fairest examination of it, by a body of men of such capacity and character that their decision shall be accepted by all. We have, therefore, thought it desirable to have an examination of the wall covered by this Report made by three engineers of the first eminence, and to invite their suggestions as to the remedy to be applied, if any is thought necessary by them.

That we may secure the utmost impartiality in this investigation, we have deemed it proper to request your Honor, as the Chief Magistrate of the city, to name three suitable persons for this purpose.

The Report of Chief Engineer G. S. Greene, Jr., referred to above is next given. From it we make extract of so much as gives the general plan of the original work; and we refer the reader for the details of the examination of the diver to the report as published.

It is addressed to the Chairman of the Executive Committee, and runs as follows:

Immediately after my appointment to the position I now hold in this Department, I received a communication from the Executive Committee, calling my attention to certain reports received by said Committee in relation to the Canal Street section of the bulkhead wall, and requesting "that you will make a most thorough investigation and examination as to the character of the work performed, and the manner of constructing the section of wall referred to, and report to them in writing the result, and your opinion in regard to the construction of said wall."

In accordance with the above I have made constant examination of the Canal Street section, and have also examined the King Street section, which was built upon the same plan and principle, and have devoted as much time as possible to this subject, consistent with my other duties. The examination of these walls has taken much time, because the greater part of them lies under water, and had to be examined by means of divers in armor; and although I have not yet been able to make so complete an examination as I wish to, I have ascertained certain facts in regard to them, which I deem it my duty to lay before you at the earliest possible moment.

The Canal Street section embraces ninety feet of wall, completed before my appointment, and in front of which New Pier No. 34 was also built before my arrival on the field, and about ninety feet more in progress of construction at that time. Upon examining the method of the work I found it necessary to at once make several changes in the details, and although feeling a lack of confidence in the principle of construction, I decided to allow this portion of the wall under construction to be finished, taking care that the method of doing the work and the details should be such as to secure a good result if the principle admitted it.

The general plan of construction was as follows: The mud was dredged out on the site of the wall to about twenty feet below mean low water. Round piles were then driven for the wall to rest upon, by means of a follower, to such depth that their heads, or tops, were about fourteen feet below mean low water. A box or wet caisson was then constructed around the round piles, to give shape to the concrete and prevent the cement from being washed away before it had time to set. This caisson was built by driving square piles about eight feet apart and placing shutters or panels of plank between them. It was not intended to shut out the water, but to prevent currents from washing the concrete, and to give the concrete shape and hold it in position until it had become hardened or "set."

The spaces between the round piles were then filled in with small stone, to about sixteen feet below mean low water, the outside of the caisson being embanked at the same time and to the same height with rip-rap stone.

The interior of the caisson was then filled with concrete, lowered through the water in a box, and deposited by opening the box near the bottom, and allowing the concrete to fall out upon the small stone lying between the piles, and upon and around the piles, to the height of about twelve feet, or two feet two inches below mean low water.

At this point the top of the concrete was leveled to receive the first or bottom course of the granite facing, which was then laid, course by course, to the top of the wall, the concrete backing being also raised to correspond with the courses of granite as each was laid.

* * * * * *

(Here follows detailed account of examination of the diver, which we omit for want of space.)

In regard to the plan of driving piles to such depth that their heads should be fourteen feet under low water mark, by follower, and placing concrete upon them without cutting of or squaring their tops, I thought it impossible that any piles driven so hard as they must be, for such a purpose, could be in a fit condition to bear the weight of the wall. I therefore procured a pile-cutter and had the heads of the piles just driven at Clarkson Street section cut off, at a depth of about fifteen feet below low water.

The result proved as I had anticipated. The pile heads, as they came up, when sawed off, were split into several pieces, broomed up, and damaged so as to be unfit for bearing any weight whatever. A record was kept of each pile head, showing the position of the pile from which it was cut, and its condition as to being split or broomed up.

The proportions were—one-half in very bad condition indeed, one-sixth in bad condition, and the remaining one-third of the whole in passable order. The pile heads were all saved, and can be seen at Clarkson Street, and also at Canal Street, south of New Pier No. 34, where they have just been cut off in similiar manner, and with same result. There is no doubt whatever that the pile heads must be cut off in all cases, before placing any weight upon them, to a good

and solid part of the pile, so that the wall may rest upon a firm and solid bearing.

The facts ascertained in my examinations thus far as described above, and consisting principally of the softness and want of cohesion of the concrete in the King Street section, the falling off of whole panels to the depth, on the face of the wall, of from nine inches to fifteen inches from top to bottom, the falling off of the lower half of wall to the depth, on its face, of two feet at the Canal Street section, and the condition of the piece of concrete brought up from the rear of the Canal Street section, indicate clearly that the plan of building the wall of concrete placed under water "en masse," "in situ," cannot be relied upon to produce a permanent, stable and durable wall; and I am under the necessity of recommending at least the suspension, if not the entire abandonment of such a plan.

No wall has been built upon this plan since my accession to office, except that part of the Canal Street section begun before I was appointed, and since then completed. The work of building the bulkhead wall is now suspended by my orders, and I shall desire to have the approval by the Board of my action.

In consideration of the fact that this plan of building the wall is highly commended in the Report of the late Engineer-in-Chief of this Department, dated 1st June, 1875, and that such Report has been made public, and extracts from it printed in the newspapers and in VAN NOSTRAND'S ENGINEERING MAGAZINE, I beg leave to suggest to the Board of Commissioners, through your Committee, the propriety, for the justification of the Commissioners and of myself, of calling to our assistance the united wisdom and experience of disinterested engineers, to examine the condition of that portion of the wall referred to in this Report, and advise what remedy, if any, should be applied to it.

The engineers appointed were John Newton, General Q. A. Gillmore, and Wm. E. Worthen.

They present a preliminary Report, which is herewith given entire:

TO THE COMMISSIONERS OF DOCKS, New York City:

Gentlemen:—We have the honor to submit this preliminary report with respect to the condition of the Bulk-head Walls at the foot of Canal and King Streets, North River, upon which our opinion was solicited.

The scope of inquiry submitted to us is briefly set forth in a communication addressed to us by His Honor the Mayor, dated Oct. 12, 1875, and is comprised in the following extracts, viz:

"You are requested to make an examination of the bulk-head walls, now partially constructed at Canal and King Streets, North River, and report to the Department of Docks, at the earliest day practicable, the facts as to the condition of such structure, together with your opinion as to their safety and durability.

"You are requested also to communicate your advice as to completing such structures, either with or without modification of the plan of construction; and to give your advice as to what, if anything, should be done with those structures."

We were further requested by your Department in a communication dated the 8th inst., to express definitely our opinion "in regard to the system employed in said constructions."

On the receipt of the Mayor's communication, we immediately entered on our duties and commenced an examination of the King Street and Canal Street bulkheads, the Department of Docks having previously sunk a shaft in the center of the King Street bulk-head, and constructed and placed a three-sided caisson against its face. We have now, with the aid of divers made thorough examinations of all the exposed faces of both bulk-heads, the examinations of important points being by two divers at different times, thereby checking their reports. The water has been pumped out of the caisson and the shaft at King Street, and we have made a personal examination of the exterior face and center of the wall. We have also had a shaft sunk in the center of the Canal Street wall, and have had a caisson constructed there, in which we are making trial of concrete construction under as nearly as possible the same conditions as those under which the bulk-head was made; in

fact a model on a large scale of the wall itself. When the concrete shall have become sufficiently set, the caisson will be raised, and the condition of the concrete can be readily examined. We are also having experiments made of the comparative set and strength of concrete of Portland and Rosendale cements, in the position and under the circumstances obtaining in the construction of the bulkhead. All these experiments require time for the setting of the cement, and are at present incomplete. We cannot therefore at present give a full answer to all the queries proposed, but in answer to your first interrogatory, "*the facts as to the conditions of such structures, together with your opinion as to their safety and durability,*" we would respectively report that, from all our examinations, we find that the mode of construction adopted, in connection with the details, appliances and materials used, is uncertain in its results.

We have found that the component parts of the concrete have settled in layers, or strata with varying proportions of cement; that the broken stone and sand are in excess at the bottom of layer, and the cement at the top; that the cement has washed out and deposited itself as *laitance*, in combination with the soil in the water in layers by themselves, presenting the appearance of seams between the different layers of concrete, or of pockets in spaces in the concrete. Many portions of the wall we find strong, with a good set, but the faces almost invariably weak and the set imperfect; but we do not find any but the slightest settlement or delignment of the wall, nor is it probable that either of these will increase to any injurious or unsightly extent, whilst the bulkheads remain under their present conditions, without back-filling. But, before the earth filling is put in behind the walls we should propose some further protection against the thrust outwards of the embankment.

Whatever of weakness there may be in the present structures we think it may be remedied without any removal of structure or any large expenditure. We would propose at any rate to leave it as it is for the present.

We do not wish to be understood as condemning, as a system, the method of constructing submarine masonry by passing mixed concrete through and depositing it in the water. On the contrary, it is well known that excellent work can be executed in that manner under suitable precautions in respect to the quality of the cement used, the proportions of the cement to the coarse ingredients, the kind of apparatus employed in laying it, and the care with which it is operated.

Our criticisms will be more fully set forth in our final report, and will refer to the details of the method of construction adopted for the Canal and King Street sections.

Our final report, which will give in full all the facts obtained in our examinations, with the results of our experiments, will be completed within the coming month. In it we will endeavor to give satisfactory answers to all the interrogations submitted to us, and we suggest that nothing be done in the meantime towards completing those portions of the walls for which the pile foundation has been wholly or partially prepared.

From the final report of the engineers, which immediately follows the above, we make extract of the description of their tests of cements, referred to in the preceding document:

EXPERIMENTAL TESTS IN CASKS.

In order to test the qualities of Rosendale and Portland cement under the same circumstances of exposure, mixed with different proportions of sand and broken stone, eight varieties of concrete were deposited in casks under water January 3d, and taken out and examined January 21, 1876.

The casks were of forty-five gallon capacity, and were pierced with one-inch auger holes on all sides, the holes being three inches apart between centers horizontally, and from three to five inches apart vertically. The bottoms were pierced in a similar manner, the holes being three inches apart between centers both ways. Four-inch rubble-stones, of the kind used around the pile-heads under the Canal and King Streets walls, were then put in the bottom of each cask to the depth of nine to ten inches, and they were then set in the water alongside of the wall at the foot of Canal Street,

so as to be entirely submerged, the tops of the casks being about six inches below the surface of the water. The concrete, as soon as mixed, was taken up with shovels and deposited in the several casks until they were filled, one after the other. The shovelful of concrete was in each case passed through the water until it reached the place of deposit, when it was tipped so as to allow the concrete to slide off.

In this condition they were left for eighteen days, constantly submerged, with the exception of two or three occasions, when they were partly out of water for a short time. On January 13th, at three P. M., when the temperature was several degrees below the freezing point, the tide fell about eighteen inches below the tops of the casks.

Subsequently, their tops were again exposed, for about six inches. On the eighteenth day after immersion, they were all raised, opened on the sides by removing several staves, and carefully inspected by cutting into the body of the concrete. The kinds and proportions of materials used in each cask, and the condition of the concrete at the time of examination are given below.

The Portland cement was the kind used in the foundations of the Canal and King Streets walls, and of good quality.

The Rosendale cement was manufactured by F. O. Norton. It was selected from his stock on hand, some of it being rather quicker setting than the rest, though not conspicuously so.

NUMBER ONE.

Portland cement, measured dry ...	3 volumes.
Sand, measured damp	5 "
Broken stone.....	10 "

This concrete was in all respects like the best quality used in the foundations of the Canal Street and King Street walls.

On examination, the cement and sand were found to be badly washed out from the broken stone on all sides next the barrel, and in the lower portions next the rubble-stones, leaving numerous voids in the mass.

Considerable sand and cement were found among the rubble at the bottom of cask, and some had evidently washed out through the auger holes. Where not washed out, the set of the concrete was pretty good. Near the top of the cask the concrete was free from voids, and of much better quality than below. The set was quite hard on top.

NUMBER TWO.

Portland cement, measured dry...	2 volumes.
Common lime, slaked to powder..	1½ "
Sand, measured damp.....	5 "
Broken stone.....	10 "

The cement and sand were badly washed out all around next the cask, and also, to some extent, but not so badly, through the mass. Poor set next the cask, but good set in middle, away from the wash. Very little mortar left among the stone next the cask, for about three inches all around. Set somewhat better than in Number One, and sand retained better in the heart of the mass.

NUMBER THREE.

Rosendale cement, dry	2½ volumes.
Damp sand	5 "
Broken stone.....	10 "

Cement and sand washed out around outside, next the cask, but not badly. Also, washed out for some distance above the large rubble-stones. Very little set, except in the upper portions. Too much sand was used in the mortar.

NUMBER FOUR.

Rosendale cement, dry.....	4 volumes.
Common lime, slaked to powder...	1½ "
Damp sand.....	5 "
Broken stone.....	10 "

Main bulk of concrete good, and no washing out of the cement and sand except a very little at bottom next the rubble-stones. The mortar retained its constituents throughout the mass, and there were no voids, except at bottom as above noted. Good adhesion of mortar to stone, and a very good set. Concrete satisfactory.

NUMBER FIVE.

Rosendale cement, quick-setting..	5 volumes.
Damp sand.....	5 "
Broken stone.....	10 "

The same remarks apply to this concrete as to Number Four, except that it had set a little harder, and on that account might be pronounced a little better.

NUMBER SIX.

Slow-setting Rosendale cement, dry	5 volumes.
Damp sand.....	5 "
Broken stone.....	10 "

Very little sifting or washing out of cement and sand, and very good concrete.

The set was satisfactory, and the mass well held together.

NUMBER SEVEN.

Slow-setting Rosendale cement, dry	4	volumes.
Common lime, slaked to powder ..	1½	"
Damp sand.....	5	"
Broken stone.....10		"

Very little cement and sand washed out, and that only close to sides of cask, and directly next the rubble-stones. No voids in concrete elsewhere.

Good adhesion of mortar to stones, and very good concrete as a whole. Set not quite so good as in Number Five. Cask well filled out all around.

NUMBER EIGHT.

Slow-setting Rosendale cement, dry	4	volumes.
Quicklime (not slaked).....	1	"
Damp sand.....	5	"
Broken stone.....10		"

The cement, sand and lime remained well mixed, and there was little, if any, washing out from among the stones. Some traces of lime, but no sand among the rubble-stones below. There was very little set in the concrete.

The best out of these eight kinds of concrete are Numbers Four, Five, Six and Seven. There being very little difference in the hydraulic activity of the Rosendale cement used, Number Four should give the same result as Number Seven, and Number Five the same as Number Six. So little difference was exhibited among these four specimens, that the propriety of cheapening the concrete by replacing a portion of the cement with common lime cannot be doubted.

We can only give from the remainder of the report the "Remarks" of General Gillmore, upon the properties and uses of the cements generally employed in such cases:

REMARKS.

First. Portland cement, with respect to the amount of clay—that is, silica and alumina—which the artificial mixture or the natural stone contains previous to burning, occupies an intermediate place between the ordinary hydraulic limes of commerce used throughout Europe, and the quick-setting argillaceous and argillo-magnesian cements, such as the Roman, the Vassy, the Rosendale, the Cumberland, and other American cements. The hydraulic limes contain less clay than the Portland cement, and the quick-setting cements more.

Second. During the burning of a stone which yields hydraulic lime, all the silica and alumina combine with lime, producing silicate of lime, silicate of alumina, aluminate of lime, and other combinations. These are the compounds, which, after water is added, undergo a species of crystalization, technically called *setting*, which constitutes the hydraulic property. But there is in the burnt product an excess of uncombined or quick lime, sufficient to cause it to slake to powder in the presence of water, in the same manner as common lime slakes, though much less promptly, especially if the excess of quicklime be small. A paste of hydraulic lime is somewhat unctuous to the touch, and sticky and soapy, although less so than a paste of common lime. When a mass of it is placed in water, it will gradually enlarge itself laterally by spreading out in all directions in consequence of its weight and plasticity. In doing so, it will usually present the same surface constantly to the water, and will not crack up into numerous pieces, or fall asunder into a lumpy or granulated mass. Hence a mortar of hydraulic lime, if quietly deposited under water, will not generally become washed out so badly as to separate the sand from the lime, but the particles of sand will be mechanically held in place by the lime paste during the time while the mass is assuming a state of rest and equilibrium, after which it will gradually indurate by *setting*. The water must be as quiet as possible, and all currents that might wash away the lime from the sand be avoided.

Third. When a hydraulic lime, after burning, cannot be slaked to a powder or paste water, but must be reduced by grinding, it is called a cement; and, if it contain certain proportions of silica, alumina and lime, it will yield Portland cement. The composition of a mixture, whether natural or artificial, that will produce Portland cement, is such that, when burned at a high heat, the silica, alumina and lime enter into combinations with each other, and form those combinations which confer the hydraulic energy, leaving neither ingredient in excess as an adulterating constituent.

It is to this circumstance, in part, that Portland cement owes its superiority. When finely ground, a heavy, sharp, and minutely granulated powder (the Portland cement of commerce) is produced. If mixed with water into a stiff paste, it is, in great measure, destitute of those unctuous and adhesive properties which characterize a paste of common or hydraulic lime. It may be said to possess little cohesiveness until it begins to set, which ensues two, three or four hours after mixing, depending on its qualities. A plastic cake of it, immersed in water, will not gradually spread itself out in the same manner as the lime paste, but will, unless it be rather flat and thin, with gentle slopes on all sides, break down all around by the sliding off, successively, of the exterior portions, thus constantly presenting a new surface to the wash of the surrounding water, until it retains the angle of repose. When the cake is of such form that no cracking or disintegration takes place when immersed—that is, when it is comparatively flat and broad—it will set and harden with great energy under water. Indeed, the most advantageous conditions for its hardening are secured in the water, or in a constantly wet place, provided the initial set can begin in the open air, or the immersion can be made without drowning out the material, which always results in separating the finer from the coarser particles, and the loss of the former, in a greater or less degree, in the form of *laitance*, and in the case of mortar in the separation of the cement from the sand, and the deposition of each material in layers or pockets by itself. In this process the sand, being the heavier of the two, will go to the bottom. The evil results are more serious with the slow than the quick-setting pure cements, for the simple reason that the disintegration is arrested as soon as the induration fairly begins. When any kind of hydraulic cement, or cement-concrete, is deposited in water, some of its lighter particles are washed out and held for a time in suspension in the water. They afterwards subside as a layer upon the top of the mortar or concrete, and, if not removed, interpose themselves between contiguous layers. As they possess very little, if any, hydraulic energy, they are elements of weakness in the mass in preventing the requisite continuity and bond. The French engineers call this material *laitance*. It is not only an injury in itself by producing seams in the mass, but injures the quality of the cement from which it is extracted. Its volume will be great in proportion to the amount of washing to which the mortar is subjected in the process of its deposition. Some cements receive more injury by washing, and yield more *laitance* than others.

Fourth. When the Roman or the Rosendale cements, and cements of like character, are burnt, all, or nearly all, of the lime and magnesia which they contain enters into combination with the silica and alumina of the clay, in the formation of those compounds which confer the hydraulic properties, leaving, however, an excess of uncombined clay, which acts as an adulterating ingredient in the cement. The burning takes place at a lower heat, and the compounds formed crystalize or set more promptly than those of Portland cement. The free or uncombined clay in the product renders the paste of these low-burnt cements somewhat unctuous, cohesive and sticky. The powder is less granular, and possesses much less weight than Portland cement, and, when made into mortar, it seems to hold the sand better. If this is not, in fact, the case to any great degree, its quick-setting properties render it superior to a cement that sets slowly, for all kinds of submarine work where the mortar has to be immersed in the plastic state. Rosendale cement of active quality, if made into a plastic ball or sphere of three-quarter inch to one inch in diameter, and immersed in water, will harden without rupture or change of form, and, at the end of about an hour, can be rolled across a room upon the floor without breaking.

No good Portland cement will sustain this test; yet, if both be allowed to set in the air, and are then placed under water, or in a damp place for five or six days, the Portland cement, mixed with three and a-half times its volume of sand, will make as strong a mortar as Rosendale cement without sand.

M. Leblanc, Engineer des Ponts et Chaussees (see Annales for 1865) says that heavy Portland cement only, such as weighs not less than 105 pounds of

the struck bushel, should be used for important works—a statement which he could not have made had he been familiar with the best American cements, and the history and results of their use upon our public works during the last forty years. I have been a constant advocate of Portland cement as a substitute for Rosendale for general use, with certain marked exceptions, for the reason that, when very strong work is required, its superior strength gives it a great advantage, while for common masonry, in large masses, where inertia is desired rather than strength, it will bear adulteration with common lime and sand to such degree as to bring the cost of the work even below the cheapest that can be produced with the Rosendale, or any equivalent American cement. For the fabrication of concrete, however, to be deposited to take its first set in water, I have never recommended it, not because it is incapable of yielding excellent work under such circumstances, but because the conditions, necessary to secure excellence, can only be established and maintained under the most careful personal supervision, such as a superintending engineer is seldom able to give. When those conditions can be secured there is no doubt of its superiority to Rosendale, or any other light, quick-setting cement. M. Leblanc further states, that Portland cement concrete, immersed in water, undergoes an energetic weakening, or washing-out; that the broken stone, as soon as it touches the water, is deprived of its mortar, in fact, keeps no trace of it; that Portland mortar is not fat and soapy like lime mortar, and does not stick to the trowel; that, poured into sea water, this concrete arranges itself in three parts or beds, the upper portion being a thick, milky solution, with no power to set, and remaining soapy unless dried. The second portion resembles meagre mortar. The lower stratum alone appears to preserve its quality; but being composed of the heaviest and most highly burned grains, it sets very slowly, and, besides, is weakened by mixture with the larger proportion of gravel forming the mortar, which falls down with it through the interstices of the broken stone. M. Leblanc also remarks that, when concrete is deposited in water from boxes, they should be as large as practicable, but that if it be absolutely necessary to use it under water, it is best to employ a *trêmie* in preference to any other apparatus; also, that Portland concrete may be spread out under water with less alteration than a bed of lime mortar concrete, *provided*, that steep slopes and the rolling of the stones on the surface are avoided, which can be accomplished sufficiently easy with the *trêmie*. It is not attempted to give a translation of M. Leblanc's paper, but only a summary of his opinions, so far as they bear upon the subject under consideration. He is an advocate of the use of freshly-mixed Portland concrete in the water, under such precautions as will secure it against injurious wash.

Fifth. It will be inferred from the foregoing that, in order to produce good submarine masonry by depositing freshly-mixed concrete in the water, certain precautions are necessary, viz.:

(*a*) The cementing material should possess the properties of unctuousness and adhesiveness, to enable it to retain the sand while the concrete is assuming a state of rest in the water; and it should be able, in as great degree as possible, to assume that state, by flattening out and spreading, rather than by breaking down and rolling off on the sides of the mass deposited.

(*b*) If it be deficient in the properties last named, it should, in lieu thereof, be quick-setting, in order that the washing-out of the sand and its separation from the cement may be arrested in a few minutes after deposition, by the prompt induration of the cement.

(*c*) If a box is used for depositing the concrete, the form of the box and the manner of emptying it should be such that the concrete will be subjected to as little wash as possible. Hence, a large box is preferable to a small one, as it will expose a less area of surface in proportion to the volume deposited. For example, a box three feet long by three wide by two feet high, will hold eighteen cubic feet, and has a surface area of forty-two square feet, equal to two and one-third square feet to each cubic foot; while a box of the same form, but six feet wide by six feet long by four feet high, will hold 144 cubic feet, and has a surface area of only 168 square feet,

equal to one and one-sixth square feet to each cubic foot.

(*d*) The form of the box used in laying the foundation of the King St. and Canal St. sections is objectionable. It has no cover on top, so that the exposed surface of the mixture, equal in itself to one square foot to every two cubic feet of volume, was subjected to a rush of water over it during its descent to the bottom, and the contents, instead of being deposited in their allotted place in a compact mass, issued in a manner much resembling a stream. Moreover, the side door of the box fitted so imperfectly, that the water entered quite freely around its edges and forced its way through the concrete to the top before the box became submerged. A box, operated on the clam-shell plan, would have been better ; but preferable to any box is the *trêmie*, when properly constructed and operated, as the concrete laid with it never touches the water until it issues from the bottom of the *trêmie* in the spot where it is to remain, without further disturbance, except what may be caused when the next layer is deposited upon it. It is laid under a constant pressure from the weight of the column of concrete in the *trêmie* shaft, which, with a *trêmie* twenty feet long, would amount to about one and a half tons per square foot. A *trêmie* is operated in a vertical position and is freely open at both ends. The spout used for a time by the Department of Docks, was closed at the lower end, and the concrete issued in a stream from an opening on one side. As a matter of course, it was badly washed.

Sixth. A glance at the inspection notes shows that, while the concrete is by no means good in average quality, and in many places is very bad, in the Canal Street and King Street walls, this inferiority differs in the two cases, both in kind and extent.

The Canal Street wall is traversed by several bad seams of soft material, collected as sediment upon the surface of some of the layers of concrete, and, therefore, separating contiguous layers. In some places a probe can be thrust into this mixture, by hand, to a depth of several feet, being finally arrested, apparently, by the broken stone in the concrete, either above or below. Much of the material of these seams is entirely destitute of hydraulic properties, and does not get hard when dried, but becomes light, spongy and easily pulverized between the fingers. The *laitance* produced when Portland cement is placed in pure sea water is slightly dydraulic and, although its interposition as strata in the concrete breaks its continuity and impairs its strength as a monolith, the injury is trifling when the strata are thin and few in number, as they always will be when the work is vigorously pushed with thick layers.

Seventh. That portion of the Canal Street wall which came under my inspection was the eleven uncovered panels in the rear, situated between the middle of Pier 34 and the north end of the wall. The seams here vary in width from three-eighth inch to three inches, and, in depth, as ascertained with a probe, from three or four inches up to three feet. They are, doubtless, much deeper in some places but, as they are interposed between undulating and irregular, instead of plane, surfaces, the probe would be stopped by the broken stone of the adjacent concrete. The material of the seams was generally of a whitish color, composed mostly of *laitance*, with some river filth and sewage.

In several places, the bottom, or heel, of the wall is broken under to a depth varying in the different panels from one to three feet. This is due to the relatively inferior character of the concrete composing the bottom layer, which, on being emptied from the box, at the pile-heads, fell through the water a height of from one to three feet before it found a resting place on the broken stone. It was therefore subjected to severe washing, and parted with much of its cement and sand, the lighter portion of the cement floating away in the water, to be subsequently deposited as a seam, while the heavier particles, together with the sand, settled down among the rubble-stone below.

Several soft places were found in the face of the concrete, besides the seams ; and some of these contained no stone, but only soft washed-out cement, or cement and sand, either mixed together or in separate layers. These weak places were, doubtless, caused by the settlement of cement, sand and *laitance* into the

depressions next the shutters, left between contiguous boxes of concrete, thus filling these depressions or cavities to such degree that the concrete subsequently deposited could not flow into and fill them.

The concrete in the heart of the wall, as shown by the shaft sunk from the top, is superior to that on the back next the caisson, and, with the exception of a few seams, is of fair average quality.

At the King Street wall the shutters had been removed from twelve panels on the front, and from seventeen panels on the rear, the whole number of panels being nineteen on each side, in a total length of 146½ feet.

Diver Burt examined all the uncovered panels in front and rear. A second examination of those in front was subsequently made by Diver Conklin.

The seams occur less frequently, and are fewer in number, and of less length along the face, in the King Street than in the Canal Street wall. They are also of less depth, as indicated by the penetration of the probe; and, on the whole, do not constitute such an element of weakness as to require that any special precautions should be taken to guard against it.

Eighth. The hardness of the concrete in the two walls was frequently tried, in a rough way, by digging small holes in the face, care being taken to select spots where there was no exceptional softness due to the existence of seams. The instrument used was a common stone drill, twenty-one inches long, made from one-inch octagon steel, having on one end a dull chisel edge three-fourths of an inch wide. It was thought that, by employing the same diver with a similar drill at some future time, the progressive induration of the concrete could be approximately determined. The test-holes resembled in form the small end of an egg. The width at the face of the wall, and the depth, as well as the time occupied in digging the hole, was recorded in each case, and will be found in the notes of inspection. Nineteen of these holes—five in front and fourteen in rear—were dug in the King Street wall, and eight in that portion of the rear of the Canal Street wall, which came under my inspection. The holes were of various sizes,—from the smallest, which was two and a half inches deep and three inches wide, to the largest, which was twelve inches deep and twelve inches wide, and the time occupied in digging them varied from three to eleven minutes. The average depth of those in the King Street wall was seven one-ninth inches, the average width, seven one-sixth inches, and the average time required to drill them, six one-sixth minutes. At the Canal Street wall the average depth was five one-fifth inches, the average width five one-fourth inches, and the average time, five and a half minutes.

These facts, although interesting, are only of practical value in connection with a future examination by the same diver with the same or a similar instrument. No hammer was used, but the drill was worked in with one hand.

Ninth. A characteristic feature, which may correctly be termed a weakness of the King Street wall, is due to the comparative inferiority of the concrete, in the first or lower layer, deposited around and upon the pile-heads. The causes of this inferiority have already been mentioned. Its results are of a marked and somewhat important character, for the toe of the concrete base is so badly broken off and caved under, that the front row of piles, located directly under it, give very little, if any, support to the wall, and should, for safety, be disregarded in calculating the stability of the structure. The effect of this is to place the toe of the wall at the second row of piles two feet back, and, therefore, to diminish the thickness of the wall, at the base, two feet.

As the piles of the second row, and of all the other rows in rear of it, except the one under the heel of the wall, were left extending above the rubble-stone, they doubtless have a good hold on the better concrete of the upper portion of the lower layer, or of the second layer, into which many of them reach.

Another feature of the King Street wall is that, in many places, the face of the concrete base has fallen off to a greater or less depth throughout its entire height. In some panels the amount thus lost is trifling; in others it averages nearly a foot in horizontal thickness; while many preserve their original face almost intact. This loss of

concrete does not increase the weakness caused by the breaking under of the toe of the wall, for the reason that the part lost is simply a portion of an overhang, all of which could, without further impairing the stability of the structure, be spared as far back as a vertical plane tangent to the outer faces of the second row of piles.

Besides the seams there are soft places, destitute of concrete stone, in some parts of the King Street base, but not near as many as were detected at Canal Street, owing, doubtless, to the circumstance that the box used in laying the former (two cubic yards in capacity) held twice as much as the one used in laying the latter.

Tenth. In filling the experimental caisson described in the joint report, the directions given were to execute the work under precisely the same conditions which obtained in laying the concrete base of the Canal Street section, which differed from the method followed at King Street only in the capacity of the box used.

The object of that experiment was to illustrate the extent to which Portland cement concrete, deposited in the manner and with the appliances adopted in the construction of these walls, parted with its sand and the lighter portions of the cement. Besides the information sought, and assuming that the instructions were faithfully executed, the experiment brought out the additional fact that the concrete in these walls, although rich enough in cement, was not thoroughly mixed; at all events, not as thoroughly as I have always exacted upon government works, even were the concrete made by hand; while, in comparison with mill-made concrete, the degree of manipulation falls greatly below the average. Without going into lengthy details, it will suffice to state that the cement was not thoroughly and uniformly mixed with the sand, and the mortar was not well incorporated with the broken stone. Those familiar with this kind of work will readily admit that one additional turn with the shovels, if properly done, may convert an inferior mixture into a good one.

Eleventh. In my opinion, the kind of cement used, the manner of mixing the concrete, the method and the apparatus employed in laying it, and the neglect of the workmen in allowing the *laitance* and river filth to remain upon the layers, are quite sufficient, when considered together, to account for the condition in which the works were found. The exceptional inferiority of the lower course of concrete is due to exceptional causes already mentioned.

Twelfth. Instances may, and perhaps will be, cited, in which apparently the same method of construction in all its details, has given good results elsewhere. As a case in point, it has been reported to me, that the foundation of the light-house, now under construction on Race Rock, situated in Long Island Sound, some miles from New London, Conn., was laid in precisely this manner. Upon inquiry, however, I learn from the contractor that the concrete was thoroughly mixed by machinery; that the box with which it was deposited had a close-fitting door on the side so that little, if any, wash came from that direction, and that in order to diminish the wash on top, as it had no cover, a thin layer of sand was spread over the concrete before the box was lowered into the water. It may be remarked, also, that this concrete was deposited in from ten to eleven feet of water, within a boiler iron caisson, which is left in place as a part of the foundation. The material inside has never therefore been examined, except on top as the work progressed.

Some importance should doubtless be attached to the fact that this work is located in clear sea water while the dock walls stand in a mixture of sea water and sewage; for although Portland cement, if mixed up with fresh water, may be deposited in sewage water without any more retardation of the set, except in the washed-out portions, and without any greater separation of the cement from the sand than would ensue in clear water, still the parts that are separated by the sewage water, consisting of the lighter particles of cement and the *laitance*, will never indurate at all. In the Canal Street and King Street walls they constitute the seams and pockets already described. Similar seams and pockets in the Race Rock foundation would in time harden to some extent, and therefore be less positively injurious.

Thirteenth. It appears that orders were

repeatedly given to remove the *laitance* and filth from the surface of each layer of concrete before the succeeding layer was put down, but the implements placed in the hands of the diver for that purpose—a street broom and a hoe—were not calculated to do the work effectively, even if faithfully used. They could only stir up the filth, to be held temporarily in suspension in the water, and in the end to become incorporated, to a greater or less degree, with the fresh concrete, and produce pockets and seams of washed-out material, much more injurious in character than would have been formed by washing with the impure river water alone.

The usual way to remove *laitance*, and the only effective way that I know of, is to pump it out through a suction hose, with its lower end in the hands and under the control of the diver; or the hose can be managed from above, and the services of a diver dispensed with.

Fourteenth. An engineer may be willing to adopt a method of doing work which is to be executed under his constant personal supervision, or that of assistants selected and controlled by him, which he would hesitate to recommend to others who might not be similarly circumstanced.

Although I entertain no doubt whatever that, with proper care, good masonry can be made by depositing freshly-mixed concrete in water, and even in a mixture of sea water and sewage, still it must be conceded that the process is one into which elements of serious uncertainty can easily insinuate themselves, from a simple neglect, on the part of the workmen, of apparently unimportant details, and should therefore be avoided whenever it is practicable to do so, and especially in cases where the engineer in charge cannot personally superintend the daily progress of the work, or is at all restricted in the selection of his agents. When I was called into consultation with General McClellan with respect to the material and method of construction to be adopted for the masonry portion of these bulkheads or quay walls, I recommended beton blocks, laid as alternate headers and stretchers, and I have seen no occasion to modify the opinions I then held.

If I had the wall to build, as a government work, I would probably adopt the beton-in-mass method, in order to lessen its cost; using Rosendale cement concrete containing some common lime, and depositing it with a *trémie*, upon a close platform of planks resting on the pile-heads. Under those portions of the wall, where the layer of dock mud was found to be exceptionally deep, I would broaden the base of the piling by inclining the piles of the two outer rows; but generally, where conditions more favorable to stability existed, I think the bed of stone, placed around and in front of the pile-head, could be safely depended on to resist all outward movement from earth pressure in the rear.

METALLURGY IN CENTRAL AFRICA.

From "Iron."

Now that the attention of the English people has been again called to Central Africa through the discoveries and adventures of Lieut. Cameron, the following notes on and extracted from Dr. Livingstone's "Last Journal," may be of considerable interest to our readers:

When Marco Polo visited Africa in the year 1280 he found the natives producing iron by the use of bottle-shaped furnaces, six to seven feet high. The ore and fuel were placed in the furnace through the top, the molten iron being tapped from a small orifice at the bottom. The significance of civilization will impress the reader who may have followed the first traveler and noted the observations of the second as well, to see that between the two periods, no advancement whatever had been made; what Polo found in the thirteenth century, Livingstone found in the nineteenth, and precisely in the same condition.

"To the north-east of Moembe, we

have at least fifty miles of as fine land as can be seen anywhere still bearing all the marks of having once supported a prodigious iron smelting and grain-growing population. The clay pipes which are put on the nozzles of their bellows and inserted into the furnace are met with everywhere, often vitrified."

Approaching the Loendi the Doctor noticed a good deal of ferruginous conglomerate with holes in it, which, when broken, looks like red hematite. This is probably the ore used in former times by the smiths, of whose existence we now find more evidence than further east. Some furnaces are still standing near the village of Miule. Dr. Livingstone asked a chief what had become of the very large iron-smelting population of that region. The reply was that many had died of famine, and the others had fled to the west of Nyassi.

"The stones still used as anvils and sledge hammers by many of the African smiths, when considered from their point of view, show sounder sense than if they were burdened with the great weights we use. They are unacquainted with the process of case-hardening, which applied to certain parts of our anvils gives them their usefulness. An anvil of their soft iron would not do so well as a hard stone. It is true a small light one might be made, but let any one see how the hammers of their iron bend over, and round in the faces with a little work, and he will perceive that only a wild freak would induce any sensible native smith to make a mass equal to a sledge hammer and burden himself with a weight for what can be better performed by a stone. If people are settled, as on the coast, then they gladly use any mass of cast iron they may find, but never where, as in the interior, they have no certainty of remaining any length of time in one spot."

"Zomba is in a range of hills to our west, called Dzala Niama. The Portuguese in going to Casembe went still further west than this. Passing on we came to a smithy, and watched the founder at work drawing off slag from the bottom of his furnace. He broke through the hardened slag by striking it with an iron instrument inserted in the end of a pole, when the material flowed out of the small hole left for the purpose in the bottom of the furnace; the ore (probably the black oxide) was like sand, and was put in at the furnace mixed with charcoal. Only one bellows was at work, formed out of a goat skin, and the blast was very poor. Many of these furnaces, or their remains, are met with on knolls; those at work have a peculiarly tall hut built over them."

A day or two later than than this Dr. Livingstone notes the fact that he came to a smiths' village, and going still northward, he crossed the river Chiniambo flowing into the Mirongive, and he again came to a village of smiths, as he calls them, consisting of four furnaces and one smithy.

Later still he notes: "All the people came down from Pambe, and crowded to see the strangers. They know very little beyond their own affairs, though these require a good deal of knowledge, and we should be sorely put about if, without their skill, we had to maintain an existence here. Their furnaces are rather bottle-shaped, and about seven feet high by three broad. One toothless patriarch had heard of books and umbrellas, but had never seen either. The oldest inhabitant had never traveled far from the spot in which he was born, yet he has a good knowledge of soils and agriculture, hut-building, basket-making. pottery and the manufacture of bark cloths and skins for clothing, as also making of nets, traps and cordage."

At length our author reached a section of country where he found much difficulty of progress through the ignorance of the natives. He writes: "Even the smiths, who are the most plodding set of workers, are as ignorant as the others; they supply the surrounding villages with hoes and knives, and combining agriculture with handicraft, pass through life."

"The hammer," says he, "which we hear from dawn to sunset, is a large stone, bound with the strong inner bark of a tree, having loops left which form handles. Two pieces of bark form the tongs, and a big stone sunk into the ground the anvil. The men make several hoes in a day, and the metal is very good; it is all from yellow hematite, which abounds all over this part of the country. The bellows consist of two

goat skins with sticks at the open ends, which are open and shut at every blast."

"We marched northward around the end of Chisia hill and remained for the night at a blacksmiths' or rather founders' village. The occupation of founder and smith are always united, and boys taught to be smiths in Europe or India would find themselves useless if unable to smelt the ore." The furnaces are almost always placed upon an ant-hill. After crossing the Bua, he writes: "The iron trade must have been carried on for an immense time in this country, for one cannot go a quarter of a mile without meeting pieces of slag and broken pots, calcined pipes and fragments of the furnaces, which are converted by the fire into brick. It is curious that these large stone sledge hammers now in use, are not called by the name stone hammers, but by a distinct word 'kama;' Nyunds is one made of iron. The people say they were taught to smelt iron by Chisumpi, which is the name of Whelungu (God), and that they came from Lake Nyassa, originally; if so they are greatly inferior to the Mangauja on the lake in pottery."

After passing a village named Kanyenjere Mponda, he mentions that he saw fragments of titaniferous iron ore, with hematite, changed by heat, and magnetic, lay in the gully near, which had worn itself a channel.

After having crossed the Kasamba, he mentions that the trees were much used up by charcoal-burners, who in all instances were smiths too.

At a later date a hunting party came up to him, consisting of men and women, and the men were furnished with big spears, and they had a smith with them to mend any spear that might be broken, and further he says: "We now come to large masses of hematite which is ferruginous; there is conglomerate too, many quartz pebbles being intermixed. It seems as if, when the lakes existed in the lower lands, the higher levels gave forth great quantities of water from chalybeate fountains, which deposited this iron ore. Grey granite or quartz with talc in it, or gneiss lie under the hematite."

While on the banks of the Mabula, a man offered him a thick bar of copper for sale, "a foot by three inches." In Lobemba we have this note: "A great deal of copper wire is here made, the wire drawers using for one part of the process a seven-inch cable. They make a very fine wire and it is used chiefly as leglets and anklets; the chiefs' wives being laden with them and obliged to walk in a stately style from the weight; the copper comes from Katanga."

Approaching Chibue, he states: "Marks on masses of dolomite elicited the information that a party of Loanda smiths came once to this smelting ground and erected their works here. We saw an old iron furnace and masses of hematite, which seems to have been the ore universally used."

The natives are mentioned as frequently working copper, making it into ornaments for their person. Katanga seems to be the place where most or all of this is found. While among the Bangamwezi, he wrote: "They use a hammer shaped like a cone, without a handle. They have both kinds of bellows, one of goat skin, the other of wood, with a skin over the mouth of a drum, and a handle tied to the middle of it; with these they smelt pieces of the large bars of copper in a pot filled nearly full of wood ashes. The fire is surrounded by masses of ant-hills, and in these there are hollows made to receive the melted metal; the metal is poured while the pot is held in the hands, protected by wet rags."

Dr. Livingstone gives us some figures in which we have a glimpse of the business that is done by some of the traders who penetrate the interior of Africa. "Syde bin Habib is said to have amassed 5,250 lbs. of ivory and 10,500 lbs. of copper; with one hundred carriers he requires four relays, or otherwise makes the journey four times over at every stage."

Speaking of the copper at Katanga he says: "The malachite is loosened by fire, then dug out of four hills; four manehs of the ore yield one maneh of copper; but those who cultivate the soil get more wealth than those who mine the copper."

Notwithstanding the extremely crude arrangements that the natives have for converting the ore into malleable iron, Livingstone says that their ornaments are of the finest quality of iron and

"were they nearer Europe they would be as eagerly sought and bought as horse-shoe nails are for the best gun-barrels."

"Hassani, with ten slaves, dug at the malachite mines of Katanga for three months and gained 3,500 lbs. of copper."

After having met Stanley, he writes: "The cross has been used—not as a Christian emblem certainly, but from time immemorial, as the form in which the copper ingot of Katanga is moulded: this is met with quite commonly. Our capital letter I is the large form of the bars of copper, each sixty or seventy pounds in weight, seen all over Central Africa and from Katanga."

In 1872 this is written: "Glazed pipes and earthenware, used in smelting iron, show that iron was smelted in the remotest ages in Africa. These earthenware vessels and fragments of others of a finer texture were found in the delta of the Zambesi and in other parts in close association with fossil bones, which, on being touched by tongue, showed as complete an absence of animal matter as the most ancient fossils known in Europe. If vitrified iron, from the prodigious number of smelting furnaces all over the country, was known from the remotest times, the Africans seem to have had a start in the race at a time when our progenitors were grubbing up flints to save a miserable existence by the game they might kill. Slave trading seems to have been coeval with the knowledge of iron."

With a description of how wire is made, both from iron and copper by the natives, we will close: "A heavy piece of iron with a funnel-shaped hole in it, is firmly fixed in the fork of a tree. A fine rod of iron is then thrust into it and a line attached to the first few inches which can be coaxed through. A number of men haul on this line, singing and dancing in time, and thus it is drawn through the first drill; it is subsequently passed through others to render it still finer, and excellent wire is the result."

THE NARROW GAUGE IN INDIA.

From "Engineering."

THE more determined and less informed opponents of narrow-gauge railways have never scrupled, nor do they now scruple, to represent or mis-represent the course adopted by the Indian Government in altering the gauge of the Indus Valley and Peshawur or "frontier lines" as implying a condemnation of the narrow-gauge system in its entirety, so far as India is concerned. Indeed, an allusion to the change of guage for the above lines, in a recent article in the *Times*, has been taken by some critics as evidence that the celebrated "meter-gauge" State railways have not given satisfaction, and that the rails are to be taken up and relaid to the five feet six inch or normal gauge. Such an assumption is not only entirely without foundation, but mischievous, and it cannot therefore be too emphatically denied. We have reason to know that that the decision of the Indian Government, some half dozen years ago, to adopt a narrow gauge for the "State Railways" has been entirely justified by the results, and that nothing is further from their intentions, now they have had the advantage of the experience of constructing and working many hundreds of miles of narrow-gauge railways, than to abandon the system and revert to the original costly inconvenient five feet six inches gauge.

It is true that one of Lord Salisbury's earliest official acts as Secretary of State for India was to decree the reversion of the previous decision to construct the Indus Valley Railway on the meter gauge. It is true also that his lordship decided that the line between Lahore and Peshawur, should be constructed on the standard gauge of five feet six inches, "if considerations derived from the advanced state of the works" should not, in the opinion of the Viceroy, make

this course inexpedient. It is true that "as soon as the decision to alter the gauge for the Indus Valley Railway was known in India, steps were taken for giving effect to it," and that "by a resolution passed by the Governor-General in Council on the 3d August, 1874, it was decided that the Punjab Northern Railway (Lahore and Peshawur) should be constructed on the five feet six inch gauge, light rails being used, and certain works being so executed in the first instance as to be capable of being subsequently strengthened and made uniform in all respects with the Indus Valley line." It is *not* true, however, that the grounds for this reversal of the original decision were afforded by new facts elicited or unexpected disadvantages experienced in the practical working of the meter-gauge lines; nor is it to be assumed that the Indian Government, after mature consideration and consultation with eminent home engineers, deliberately accepted the narrow-gauge system as offering important financial and practical advantages, only to throw it over upon the first slight pressure from without, as a question of but little practical moment after all.

The sole reason for the reversal of their decision in the solitary instance of the "frontier lines" was the attachment of greater weight to the political and military objections, urged from the first, to the break of gauge, which would be the necessary consequence of the adoption of the meter gauge in this instance. Any saving in first cost and subsequent working was considered to be perfectly immaterial in comparison with imperial interests, and it was considered by the military authorities that under certain remote contingencies these might suffer if a break of gauge occurred at Lahore. It should not be forgotten by those who make use of this change of decision on the part of the Indian Government as an argument against narrow-gauge railways, that the course finally adopted by the Government is precisely in accordance with the recommendations of Mr. Fowler, whose advice they sought in 1870, previous to coming to their first decision to adopt the meter gauge for the Indus Valley and Peshawur lines. In his report to the Secretary of State for India Mr. Fowler observes: "Although I feel no hesitation as to the best gauge to recommend for the narrow-gauge railways in India wherever it is thought proper, on a full consideration of all the circumstances, to adopt a second gauge, I confess to a difficulty in advising as to its application or non-application in the particular case of the Indus Valley, where so large a proportion of the whole work has already been carried out on the standard gauge." If no railways had been constructed in the Indus Valley, Mr. Fowler would have been inclined to recommend a narrow gauge line, since "the financial saving would have been accomplished with a very small amount of inconvenience," but taking things as they were, the necessity of laying a third rail between Mooltan and Lahore, a distance of 214 miles, of altering the existing line between Kurrachee and Kotree, and of providing an extra supply of narrow-gauge stock for military contingencies, Mr. Fowler felt no hesitation in advising that the standard gauge should be retained, since the "cost of working and maintenance will (in the peculiar case of the Indus Valley) be less, the commercial convenience for through traffic will be greater, and in the event of political emergencies it cannot be doubted that uniformity of gauge for the railways near the Indian frontier is a matter of very considerable importance."

That Mr. Fowler fully appreciated the economy and efficiency of the narrow-gauge system, under less exceptional conditions, is sufficiently evident from the fact that almost contemporaneously with this report to the Indian Government, against the adoption of the principle in the instance of the frontier lines, he advised the Khedive to construct the proposed 500 or 600 miles of railway in the Soudan upon the three feet six inch gauge.

It is clear then that from the first the Indian Government, swayed alternately by the conflicting opinions of their civil and military advisers, exhibited much vacillation in respect of these frontier lines, although no question has ever been raised as to great advantages of the narrow gauge for all other State railways in India. It is no less certain that the final decision to adopt the normal gauge of five feet six inch for the Indus Valley

and Peshawur lines was based entirely upon Imperial considerations, and had nothing whatever to do with the question of narrow *versus* broad guage *per se*. If conclusions arrived at upon the basis of state policy and military contingencies are to be taken as precedents applicable to ordinary commercial cases, we may shortly expect to find some learned professor demonstrating the incapacity of our shipbuilders, because they continue to build iron ships for the mercantile marine of one-half inch plates, although plates of twenty times that thickness are now voted too thin by the chief constructer of Her Majesty's Navy. Such an illogical jumble of facts and deductions would be entirely in harmony with many of the arguments of the detractors of narrow-gauge railways.

It has even been attempted to draw inferences adverse to the narrow gauge from a comparison of the traffic receipts on different lines! What a conclusive argument these gentlemen would have had if the Great Indian Peninsula had only been on the meter gauge. That railway is precisely similar, as regards gauge and length, to the main line of the East Indian, that is to say both lines are on the five feet six inch gauge and 1280 miles long. The gross expenditure in 1874 on each was about £1,100,000, but the net receipts on what might have been a narrow-gauge line was only £755,000, as compared with £2,062,000 on the other line of equal length. The East Indian expended 6.66d. per train mile in maintenance and renewal of way and works, the Great Indian Peninsula 16.42d. whilst the cost of locomotive power on each line respectively was 10.63d. and 23.53d. Had there been a difference of gauge how much of this excess of cost would some theorists have attributed to the smaller diameter of wheels or the narrow guage? The latter point has been seriously urged as an important set-off against the smaller first cost of a narrow-gauge line. We would refer those interested in the subject to a Table in one of our articles on Urban Railways, in which the coal consumption per ton mile in remote and recent times is set forth. One pound of coal per mile in a good locomotive will maintain an average tractive force of 100 lbs., and consequently if we know the consumption per ton per mile in pounds we also know the effective mean tractive force or mean friction per ton, since it will be one hundred times the coal consumption. Glancing now at the Table previously referred to and multiplying the last column by 100, we find that the mean effective friction per ton—including brakes and all other sources of loss—averaged eighteen pounds, in the instance of some one thousand million train-mile tons on the Great Northern Railway, and amounts ranging from eleven pounds to twenty-three pounds in other instances. It is obvious, therefore, that any increase of fractional resistance which could result from the smaller wheels of ordinary narrow-gauge stock would affect the tractive force far less than might at first sight be supposed. An increase of twenty-five per cent. in the journal friction would be only one pound per ton, which we now see would be an increase of $\frac{1}{18}$th only in the average tractive force on the Great Northern Railway. Hence, even without making any allowance for lighter stock, the apparent disadvantage of smaller wheels becomes utterly inappreciable in the total traffic charges. Reducing it to a money value, and expressing the *theoretical* increase in thousandths of a penny per ton per mile, it will be seen that within practical limits the diameter of wheel may be introduced into gauge discussions about as wisely and usefully as the uniform of the railway staff, or any other trifling detail which lying on the surface engrosses at once the attention of superficial observers to the great amusement of practical engineers and responsible railway men.

GREAT activity is being shown in the extension of the quarrying operations in the north along the course of the Great Whinstone Dyke, in consequence of the largely increased demand for paving "setts" and other material for street and road formation purposes. The large quarries at Middleton in Teesdale and near Barnard Castle are fully employed; briskness characterises the work carried on similarly at the quarries of the Leeds Corporation as well as the private quarries in the Ayton district, and the same remark may be applied to those at Glaisdale and at Kildale.

MEASUREMENT.*

By Sir JOSEPH WHITWORTH, D. C. L., F. R. S.

From "Iron."

The two great elements in mechanics are the power of measurement and the true plane. The measuring machines which I have constructed are based upon the production of the true plane. Measures of length are obtained either by line or end measurement. The English standard yard is represented by two lines drawn across two gold studs sunk in a bronze bar about thirty-eight inches long, the temperature being at sixty-two degrees Fah. There is an insurmountable difficulty in converting line measure to end measure, and therefore it is most desirable for all standards of linear measure to be end measure. Line measure depends on sight, aided by magnifying glasses; but the accuracy of end measure is due to the sense of touch, and the delicacy of that sense is indicated by means of a mechanical multiplier.

In the case of the workshop measuring machine, the divisions on the micrometer wheel represent 10,000ths of an inch. The screw has twenty threads to an inch, and the wheel is divided into 500, which, multiplied by twenty, gives for each division the 10,000th of an inch. We find in practice that the movement of the fourth part of a division, being the 40,000th of an inch, is distinctly felt and gauged. In the case of the millionth machine, we introduce a feeling piece between one end of the bar to be measured and one end of the machine, and the movement of the micrometer wheel through one division, which is the millionth of an inch, is sufficient to cause the feeling piece to be suspended or to fall by its gravity.

The screw in the machine has twenty threads, which number, multiplied by 200—the number of teeth in the screw wheel—gives for one turn of the micrometer wheel the 4,000th of an inch, which, multiplied by 250—the number of divisions on the micrometer wheel—gives for each division one millionth of an inch. The sides of this feeling piece are true planes parallel to each other, and the ends both of the bars and the machine are true planes parallel to each other, and at right angles to the axis of the bar; thus four true planes act in concert. In practice we find that the temperature of the body exercises an important influence when dealing with such minute differences, and, practically, it is impossible to handle the pieces of metal without raising the temperature beyond sixty-two degrees. I am of opinion that the proper temperature should be approaching that of the human body, and I propose that eighty-five degrees Fah. should be adopted, and that the standards and measuring appliances should be made and kept in a room at a uniform temperature of eighty-five degrees Fah.

In many workshops we hear the workmen speak in such vague terms as a bare sixteenth or full thirty-second, but minute and accurate measurement requires to be expressed in decimals of an inch. In 1857, when President of the Institution of Mechanical Engineers, I read a paper on standard decimal measures of length, and I am happy to say that since that period the decimal system has been introduced to a certain extent in many engineers' works, but it is still far from being universal.

In the manufacture of our standard gauges, the workmen measure to the $\frac{1}{20,000}$th of an inch, and these measures are as familiar and appreciable as those of larger dimensions. As an illustration of the importance of very small differences of size, I have here cylindrical standards with a difference of the ten-thousandth of an inch. It is therefore obvious that a difference of $\frac{1}{10,000}$th of an inch is an appreciable and important quantity.

It will be once conceded that the only scale of measurement which can be used for such small differences must be a decimal one. For many years the deci-

* A paper read at the conference of the Exhibition of Scientific Instruments at South Kensington, in explanation of the measuring machine and appliances exhibited.

mal system has been in use at our works, taking the inch as the unit, and the workmen think and speak in tenths, hundredths and thousandths of an inch.

It is of great importance to the manufacturer to have the means of referring to an accurate fixed measure, as it will enable him, at any time, to reproduce a facsimile of what he has once made, and so preserve a system of sizes of the fitting parts unaltered.

The great value of the workshop measuring machine is making different gauges. Every external diameter having to work in an internal diameter should have a certain difference of size; and close observation and experience can alone determine what this difference of size ought to be. Take, for instance, a railway axle; if the bearing in which it has to work be too small, the heating of the axle by rapid rotation will be the consequence; if, on the other hand, the bearing be too large, it will be sooner worn out.

It is therefore most important, when rapid revolutions and great strains have to be undergone, that the proper difference of size, when once ascertained by experience, should be strictly adhered to.

In the manufacture of axles there should be two gauges used, the axle being made to the standard gauge and the bearing bored out to fit a difference gauge, which has to be as much larger as experience has found to be necessary, according to the conditions under which the axle has to work. Hence, every manufacturer, should be in a position to manufacture his own difference gauges. Fifty years ago the thousands of spindles in a cotton factory had each to be separately fitted into the bolster in which it had to work. At the present time all these spindles are made to gauge, and are interchangeable.

It cannot be impressed too forcibly, both upon the student in mechanics and upon the workman, that accuracy of measurement is essential for good and efficient workmanship, and that it tends to economy in all branches of manufacture, so as to have the parts interchangeable.

THE STRENGTH OF BOILERS.

From "Engineering."

In our notice of the burstings of the Manchester Steam Users' Association's experimental boiler in our number for March 24th last, we referred to the publication of the details of these experiments as a fitting addition to the works written by Sir William Fairbairn, the founder of that Association, than whom no one would have been more ready to welcome the results obtained. Viewing these experiments, and Mr. Fletcher's able exposition of them as in some degree a posthumous chapter of Fairbairn's "Useful Information," it may be instructive to compare the principles of boiler strength now enunciated by the chief engineer of the Manchester Steam User's Association with those so ably advocated by Sir William Fairbairn, and which are to-day professedly the groundwork of all boiler construction in every country.

"Useful Information for Engineers," first series, contains Mr. Fairbairn's report on the Rochdale explosion, wherein he recommends the formation of an Association for the prevention of steam boiler explosions, and such an Association was accordingly instituted in January, 1855, and it still exists as the Manchester Steam Users' Association. The principles of boiler strength given in the volume just mentioned are therefore presumably those at first adopted by the new Association. Quoting from the fourth edition, corrected, date 1864, page 52: "Every description of boiler used in manufactories, or on board of steamers, should, in my opinion, be constructed to a bursting pressure of 400 lbs. to 500 lbs. on the square inch; and locomotive engine boilers, which are subjected to a much severer duty, to a bursting pressure of 700 lbs. to 800 lbs." All through Fairbairn's writings on

boiler strength we have it repeated that every boiler should be constructed to a bursting pressure not less than 450 lbs. on the square inch. For what working pressure is this bursting strength intended? At page 55 he says, "All these accidents might be prevented, and instead of using steam which we now do in our manufactories at a pressure of five to twenty pounds on the square inch, we might with equal safety use it, and enjoy the advantage of its superior economy at sixty pounds on the square inch." Here then we find that for the then common pressure of twenty pounds per square inch in steamers and in manufactories Mr. Fairbairn advocates a bursting strength of at least 400 lbs. per square inch, that is, a factor of twenty. At page 81 he gives a less margin; he is there defining the very least he would consider could be safely worked with intelligent supervision; he says: "It would be a matter of paramount importance to the public, if men combining the greatest practical skill with the highest scientific attainments would direct their attention to the subject, and give to the public such security in the construction of boilers, as to insure them capable of bearing, under the most unfavorable circumstances, at least *six times* their working pressure."

To have still a factor of safety of *six* under the most unfavorable circumstances requires, of course, a higher factor of construction, for which the calculation supposes every part to come fairly up to its proper portion of strength, and that the workmanship and material are in every respect perfection.

Collateral with these statements by Fairbairn, we find that Fairbairn's principles have been accepted as, at least, a calculated factor of safety equal to *eight* to allow for this factor of *six* under the most unfavorable circumstances. This is stated by Rankine in "Applied Mechanics," year 1858, at page 297. "The proper factor of safety is *eight*, as for other parts of boilers." This is no doubt in accordance with Mr. Fairbairn's opinion as to what should be the factor of safety, allowing for deterioration and imperfections. In Rankine's "Marine Steam Engineering," in "Shipbuilding," at page 291, he says: "For cylindrical boiler shells, the factor of safety is from six to eight," and "as the bursting pressure should be six times the working pressure, the testing pressure should be between twice and three times the working pressure."

To understand this we must distinguish between the calculated factor of safety and the ratio of the bursting pressure to the working pressure. It seems to be considered that to insure that the latter ratio shall not exceed six, "under the most unfavorable circumstances," the calculated factor of safety of the construction should be not less than eight. In these remarks we are not giving our own thoughts on the subject, but merely what appears to us to have been the position of the question in the minds of these two eminent engineers, Fairbairn and Rankine.

In our notice last week of the discussion that followed the reading of Mr. Fletcher's paper at the recent meeting of the Institution of Mechanical Engineers last week, we observed that Mr. Fletcher stated that "In the absence of more complete experiments he thought that the present partial ones were ample justification for continuing the system of calculation of boiler shells, which he has for a long time adopted, viz., making the factor of safety four, and calculating each joint separately, not making any allowance for breaking joints, &c., as has been commonly done in a somewhat uncertain way." In recording the advancement of engineering knowledge we are here brought face to face with a very big step that has been taken "a long time since" by the chief engineer of the Manchester Steam Users' Association. It would be interesting to know whether Sir William Fairbairn took this step forward at the same time as Mr. Fletcher, or whether he ever took it at all. The alteration amounts to nearly doubling the working pressure in all boilers constructed according to Fairbairn's professed opinions of safety. Such an advancement deserves more than a mere statement of having been adopted a long time by those whose practice has been the accepted precedent for prudent manufacturers. It would have been much more satisfactory to have had Fairbairn's own statement to the public, that whereas he had all along publicly advocated that boilers even at

twenty pounds working pressure ought to be made for a bursting pressure not less than 400 pounds, and that under the most unfavorable circumstances there ought to be at least a factor of *six* between the pressure which the boiler would actually burst at and the working pressure, he had now from the experience of the Manchester Steam Users' Association become convinced that a factor equal to four, neglecting the crossing of the seams, was practically an ample margin of safety; or that a boiler calculated to burst at 320 lbs., is what can safely be employed for a working pressure of seventy-five pounds on the square inch.

We do not object to the new and more confident view of boiler strength; we think, however, that the change in the opinions held by the Manchester school of boiler designers ought to be made more patent to all concerned, and therefore we write now to draw attention to the fact. We hope that the boiler inspectors of the different associations will either adopt the new principles of strength, and so promote reasonable uniformity of practice, or that those who object to do so will at once give their reasons for holding back.

The new factor is given as *four*, neglecting the crossing of the seams and other minor considerations. The value of these will depend in a great measure upon the breadth of the plates, and will be about the same for plates of about the same thickness in similarly constructed boilers. In Fairbairn's system of calculation, the boiler shell, with plates of about the same thickness as the experimental boiler—viz., seven-sixteenth inch—was taken as being, on the whole, stronger than the mere seam by one-fourth of the difference between the strength of the seam, *per se*, and the strength of the solid plate. The strength of the plate at the seam is, in the experimental boiler, sixty-seven per cent. on the straight; $67+\frac{100-67}{4}=75\frac{1}{4}$ per cent. We have therefore, $\frac{75\frac{1}{4}\times 4}{67}=4\frac{1}{2}$ nearly, as the factor, including the same proportion of additional strength for the crossing of the seams as is allowed in Fairbairn's calculations. We have therefore four and a-half virtually substituted for eight, because the four and a-half is taking the most favorable circumstances, not "the most unfavorable," as Fairbairn has it, for the "at least *six*." The boiler actually gave way at 310 lbs., or at, say, four and one-seven times the intended working pressure, viz., seventy-five lbs.

It is principally with reference to marine boilers that the proposed decrease of the factor will be considered as perhaps authorizing an increase of working pressure. Comparing the above with a marine boiler of twelve feet diameter, made of three-fourth in. plates, and passed for sixty-two and one-half lbs. on the square-inch working pressure, we may learn what is the amount of discrepancy between the sanctioned pressures at sea and those sanctioned by the careful experiments of the chief engineer of the Manchester Steam Users' Association.

In the above example we find that the thickness of the boiler plate written in decimal parts of an inch divided by the diameter in feet gives the pressure allowed, neglecting the decimal points or multiplying by 1000.

$$\frac{.75}{12}=.0625 \text{ or } 62\tfrac{1}{2} \text{ lbs. pressure.}$$

In the experimental boiler we have a plate $\frac{7}{16}$ in. $=.4375$, the diameter of the boiler is seven feet.

$$\frac{4375}{7}=.0625 \text{ or } 62\tfrac{1}{2} \text{ lbs.}$$

We have, therefore, this result, that the pressure allowed proportionately to the section of the shell is in the marine boiler sixty-two and one-half lbs. for a boiler that if of seven-sixteen in. plates, and only seven feet in diameter would be allowed seventy-five lbs. as a land boiler by the Manchester Steam Users' Association.

In the discussion it was stated that to get the required pressure, marine boilers were now made one and one-fourth in. and even one and five-sixteen in. thick, and that such plates made boilers proportionately weaker than if of thinner plates. There is no doubt some truth in this statement, and if so the pressures allowed should be something less than proportional to the thickness of the plates when these are doubled or trebled in thickness. In the marine boiler we have cited as an example of present

practice, the pressure allowed is directly proportionate to the thickness of the plates, and inversely as the diameter of the shell, and if the strength of the land boiler is calculated by the same rule, the one boiler should have the same pressure as the other. But the land boiler which is of seven-sixteen in. plates is really allowed seventy-five lb, while the marine boiler, which is of three-quarter in. plates, is allowed sixty-two and a half lbs. The land boiler is not allowed a steam chest; the marine boiler referred to is also without a steam chest. We have taken the first marine boiler that came to our hand because it is not an old one, and because, accidentally, it coincides so exactly with the experimental boiler. Looking at the result of this experiment in boiler bursting and giving due weight to all that Mr. Fletcher has so ably set before us, and to the impression we have that very thick plates do not give proportionately as much strength in boiler shells as thin ones do, we cannot see that the working pressure of marine boilers of the very best constructions can safely be allowed to be more than is obtained by dividing 1000 times the thickness in inches of the plate of the shell by the inside diameter of the boiler in feet, which is exactly the pressure allowed in the marine boiler referred to.

There is another principle of strength of boilers that is connected with the name of Fairbairn, the collapsing pressure of circular flues. The formula given by Fairbairn for practical purposes is $P = 806{,}300 \frac{C^3}{L.D}$, where C is the thickness of the plates in inches, D the diameter of the flue in inches, L the length in feet, and P the collapsing pressure. The experiments from which this remarkable law was deduced by Sir William Fairbairn and for which he has so deservedly received so much praise, were twenty-two in number. Verifying the constant in the above formula in the Table he has given of the detailed results of these experiments, we find that the following are the constants agreeing with the individual experiments: (*See Table next column.*)

But Mr. Fairbairn gave it not as 465,314 but as 806,300 or seventy-one per cent. more than his own experiment gave on the average.

510,540?	508,300	450,000	356,900
510,540?	502,900	447,080	64[illegible].500
510,540?	474,600	428,100	370,900
468,700	474,600	446,100	535,100
444,680	510,540	353,790	
465,100	421,800	405,600	

22) 10,236 910

465,314

The explanation of this, what shall we call it?—mistake? made by Fairbairn, tacitly adopted by engineers since 1858, when the experiments were described in the *Transactions* of the Royal Society, is a very simple one. Fairbairn's experiments were principally made with very thin tubes, nineteen of the twenty-two experiments were on tubes only .043 in. in thickness. In giving up the .19 of the 2.19 power which he gave as the exact result, he virtually altered the pressure by a multiplyer equal to $.043^{.19}$, which happens to be equal to .55. The liberty taken with the fractional part of the index amounted in nineteen of the twenty-two examples to substituting 100 for 55. This seems to have been first detected by the Board of Trade engineers, and in this way perhaps may the discrepancy between their rule and that hitherto in use as Fairbairn's practical formula be accounted for.

A COMPANY has been incorporated to construct a railway from Newport—the junction of the Ryde, Newport, and Cowes Railway Company, and Isle of Wight Newport Junction Railway Company—to Yarmouth and Freshwater, with power to make agreements with the companies for traffic arrangements. At present the only railway communications in the Isle of Wight are in the eastern half of the island. The proposed Freshwater, Yarmouth, and Newport Railway, twelve miles in length, is a continuation or extension of all these lines, which center and form a junction with it at Newport, and thus this line, which will run due west, brings the north, south, and east of the island in direct communication with the west, the four lines above mentioned being feeders to it. The line will run through Newport, Carisbrook, Calbourne, Shalfleet, Thorley, Bouldnor, Yarmouth, Freshwater; and hereafter may be extended to Alum Bay, 2½ miles west of Freshwater.

SEWAGE TREATMENT.

By Capt. L. FLOWER, Sanitary Engineer, Lee Conservancy Board, &c.

From "Journal of the Society of Arts."

The Committee of the Sewage Conference having honored me by a request that I would contribute a paper on this very important subject, involving as it does the purity of the water supply of a considerable portion of London, I cannot do better than give as briefly as possible some notes made during the last few years on the watershed of the Lee, which, extending over an area of 600 square miles, and having a population of nearly 750,000 persons, has been during five years past under my sole charge, so far as the pollution of the water is concerned, and I believe I may say I am the first appointed and only officer in charge of an entire watershed area in the United Kingdom.

I must, however, state very distinctly, that my Board being very peculiarly placed, must not be considered to be bound by any opinion I may venture to express in this paper; as at present advised it refuses to approve of anything, it merely points out pollution, and orders abatement thereof.

In view of the general purification of rivers, it is a matter of discussion whether such a line of action is or is not one which tends to the consummation of the purpose for which such Boards may in future be appointed; personally I have an idea that it would be well not to draw so fine a line, and that a little encouragement should occasionally be given to willing local authorities. I do not think that Boards should identify themselves with any one special system of sewage disposal to the exclusion of all others, because experience teaches that no one process exists which is applicable to all cases alike, any more than that any one specific will cure all diseases. Each case is governed by the chemical condition of its sewage and the topographical position of its locality. Many schemes for the disposal of sewage have been tried, and some successfully so, in this watershed. It was proposed some time since that a general system of drainage should be adopted, the sewage of the valley concentrated at one point, and run into the Thames; I must say I am not an advocate for such a mode of disposal. I think it is a weak way of looking at the question, and when I find engineers and others of eminence advocating the running out of all this abomination into deep water, and so hoping to see the last of it, I ask, are these the Englishmen of whom it is said that the word "impossible" exists not in their vocabulary, and are these of the same nationality as the men who, by boldly grappling and overcoming co-called "difficulties," have made the name of Great Britain respected throughout the globe? Such "heroic treatment," to borrow an expression from a recent report on the Thames Valley, is not applicable to the valley of the Lee. It is much easier to dispose of small volumes of sewage than an aggregated quantity, and as there must be some value in the deposit, even if only used to raise low-lying ground, why throw it away, and allow it to silt up our rivers and pollute our sea frontages? Once cast a thing into the sea, and who can say where it shall turn up again.

In considering the pollutions of the River Lee, I shall confine my remarks almost entirely to water-carried sewage. Dry systems of disposal do not exist to any material extent in my jurisdiction.

So far as pollution of the water goes, we may begin with Luton, which has a population of about 20,000, and is situated close to the source of the Lee proper. Large quantities of chemical matter, used in bleaching and dyeing straw-plait, mix with the sewage of a portion of this town, and are led to a point, where, in consequence of a compromised litigation with a large landowner, the sewage is subjected to a liming process, and then passed to the Lee. The "tanks" so called are, with the exception of a very small portion, only "beds" dug into the chalk. These works, being of a temporary nature, cannot be called satisfactory, though the discharge of fluid from them, in consequence of the care with which they are carried on, and the enormous dilution of the fluid by

subsoil water, is at times fairly admissible into the river; but though clarified it is not purified, and though clear in appearance, is not such as, in my opinion, should be passed into a river out of which drinking water is drawn; moreover, in flood times the pollution is great. It was said some years since, that if sewage were mixed with twenty times its volume of water, the organic matter which it contains would be oxydized and disappear in the course of a dozen miles or so. This is not borne out by fact, and I believe we may consider that there is no river in the United Kingdom long enough to completely destroy sewage by oxydation. It may be said that Luton is a long way from London, but it is also well known that no chemical process can of itself entirely get rid of the effects of sewage contamination, and although Luton is permitted by a special clause of the Lee Act to pass clarified sewage into the river, it is to be hoped that in any future legislation, all towns which discharge into a river, out of which people have to drink, should be compelled to pass their effluent water through land or through an efficient filter before it is discharged into the stream. Burnt clay has been recommended, and was mentioned by H.R.H., the late Prince Consort, in his letter to the Royal Agricultural Society, 12th April, 1850, in the following terms:—"Burnt clay from its aluminous ingredients has the power of extracting ammonia in the alkaline salts present in sewage, and is cheaply procured.

At Luton the sludge, which like all lime deposit, is very filthy, is lifted by mechanical means from the beds, and mixed with night soil, collected from the portion of the town which is not water-closeted, and the ashes, and then sold to farmers of the district. The works are near the town and smell very badly. My Board has complained of the result of the process in use, but in the face of differing opinions on the subject has not taken upon itself the responsibility of recommending another.

The next pollution worth notice is Hatfield. This has a population of nearly 4,500; the sewage is disposed of by passing it on lands, and no pollution reaches the river.

Hertford, next in importance, with over 7,000 inhabitants, has precipitation works which were constructed at considerable cost by the New River Company some years since. An attempt was made to purify the sewage by liming it. Here again, as at Luton, the effluent, although clear, was not pure, and the adjoining town of Ware, lower down stream, was constantly complaining of the nuisance caused by secondary decomposition, which is invariably set up by the lime effluent, I believe it is a fact that the most dangerous kind of organic impurity is organic matter in process of change or putrefaction. This change is set up, and continues in the effluent after discharge from the works—the condition of the channel between the works at Luton and the stream, and the river at Ware, is evidence of this; thus, in the lime effluent, we have the worst condition of sewage. It is not the presence of organic matter in its original state which is so objectionable in sewage, but those matters which are undergoing change, in fact, putrefaction. The lime process was abandoned at Hertford, and the Phosphate Sewage Company have taken the works under contract with the Corporation. Since then I have received fewer complaints, but the same remark which I made just now as to the necessity of filtering the effluent produced by chemical process applies here. It is true that it may be said filtration is carried on at Hertford, inasmuch as small coke filters are used, but I think the area is too limited. Here again the sewage is much diluted by infiltration of subsoil water.

Ware, with 6,000 inhabitants, next comes into notice. This place formerly sent all its sewage and refuse from malting, the latter being a liquid rapidly running into decomposition and forming considerable pollution, by several outlets direct to the river; all has now, with the exception of refuse from some of the maltings, been diverted, and an entirely new system of sewers has been constructed, the sewage is discharged far below the town on to an irrigation farm close to the historically famous Rye House. It was intended that the sewage should be treated by precipitation before it was applied to the land, but that notion was abandoned. The farm is in very low-lying ground, and in flood time a large area is under water. I do not think the

sewage of Ware can be said to be satisfactorily disposed of in the Rye meads; still it soaks away somehow and until the land becomes supersaturated, I suppose it will not be easy to discover pollution. I question very much whether sewage "pure and simple" should be permitted to be discharged on to land which surrounds a place of popular public recreation, where thousands of hard-worked Londoners go for a little fresh air, and to spend perhaps their only single day's holiday in the course of the year in the country. As early as 1841 we were told, in reference to sewage irrigation, of "the offensive and injurious emanations which the sewer water gives when allowed to spread and stand upon the meadows." In these days there are those who would teach us that the presence of a sewage farm and the odors therefrom improve the health of locality. Verily there is no accounting for taste.

Waltham Abbey, with a population of over 5,000, the next town on the Lee proper, has lately been re-sewered, and, after trying several systems of filtration with more or less satisfactory results, nothing more than simple subsidence, assisted by "a dose" of lime very minute in quantity, is done with the sewage. It is then pumped on to the town mead, on low-lying land close to the river, where it soaks away, and no pollution is for the moment apparent.

We next come to the towns on the Lee below the intakes of the water companies. Enfield, with 13,000 population, has all its sewage taken into the adjoining parish of Edmonton, on to a sewage farm near Ponder's-end, which is fast becoming a pestilential swamp. It is too low, the water level of the district being little more than four feet below the average level of the land. Some time since a company, formed to work the process known as "Whitthread's Patent," which has been fully described in former journals of the Society, put up a precipitating tank, and treated a portion of the sewage. While this was in operation all went well. The effluent was sufficiently pure to be discharged into the river below the water company's intakes. The precipitated sludge was fairly dry, ready for use when wanted, and just so much liquid sewage as the tenants required for their market gardens was periodically supplied. I am informed that the expense of this process, so far as the chemical treatment was concerned, was large. The value of the disposal of sewage by a combined system was, however, fairly demonstrated here while the company lasted, some eighteen months or two years. My Board has strongly protested against the existing unsatisfactory state of affairs.

Next to this is Edmonton, with a population of 12,000. Here about a million gallons are daily discharged. Here is also a sewage farm; but, also, larger precipitating tanks. The following is the course adopted for the disposal of the sewage. On Sundays the sewage is collected in the storage reservoir at the works, which holds 1,500,000 gallons, supposed to be the flow of thirty-six to forty hours in ordinary seasons. On Mondays the pumps are worked from eight to ten hours, and the sewage is ordinarily pumped through the first tank on the land, having been first treated with a mixture "for irrigation," composed of precipitated sludge and a portion of precipitating mixture, according to Mr. Hille's system, which has been in operation here for the last six months. This is occasionally varied, and the sewage is entirely treated by precipitation after Hille's system, and then passed, in a condition which analysis proves to be unobjectionable, to our streams. The work at the sewage outfall detailed for Mondays is continued alternately, as circumstances dictate. The engines pump 75,000 gallons per hour. A piece of eight acres, adjoining the sewage tanks, is kept as a downward filtration bed; no sewage in its raw state is pumped on any of the land; the sludge, which is perfectly inoffensive, is mixed with ashes from the town, and used on the farm.

We next come to Tottenham, with at least 30,000 inhabitants, and daily increasing. This place is notorious as the birthplace—and in many instances, the grave—of several sewage processes. I will not attempt to describe them, for time does not permit, but merely give an account of what is at present in operation. Here also Mr. Hille is at work, and treats the sewage with results

which out to be satisfactory. Analysis proves the effluent to be unobjectionable, and sufficiently pure to be passed to the river. The sludge is singularly free from smell, is easily dried without artificial means; and I am informed the process is inexpensive. Mr. Hille tells that according to the accounts of the Local Board, it does not exceed 25s. a day to treat 1,200,000 gallons of this very bad sewage. Tottenham sewage is rendered all the worse by the admixture of refuse from india-rubber works, a portion of which at least finds its way to the sewers, and mixing with ammonia stinks abominably.

We learn here how valuable would have been the provision in Lord Salisbury's Bill of last session, which proposed that manufacturers should treat their own refuse on their own premises, and thus help the ultimate disposal of the sewage at the outfall of the district, a clause which I trust will form part of some future Act.

The principal pollution below Tottenham is West Ham, which, with upwards of 70,000 inhabitants sends its sewage to the tidal portion of the Lee, about 3,000,000 gallons daily. The residents in the neighborhood of the outfall at Canning Town very strongly object to the treatment of sewage by any chemical means, and negotiations have been pending sometime with the Metropolitan Board of Works as to the ultimate advisability of joining their system. The tanks here have never been seriously and continuously used, though for some months in 1872 General Scott's system was tried. Several other modes have also been experimented on.

In the tributaries of the Lee much remains to be done, but the work is going on slowly and surely—all pollutions are known; much abatement is delayed by the unwillingness of landowners to part from their land for the purpose of sewage works or sewage farms; and I cannot help remarking here, as the result of the working of our Act of Parliament that in any future legislation which may take place in regard to the general purification of the rivers of the kingdom, that punishment for offences against an Act should be sought at the hands of an independent tribunal, and not, as in our case, be left to the jurisdiction of the local magistracy, themselves in many cases the greatest offenders. I can point to some important districts where prosecutions have entirely failed.

The principal pollution of the tributaries was Bishop Stortford, with a population of about 5,000, and a large malting trade; the whole sewage and malting refuse formerly went into the ditches, which were highly offensive. Now all sewage and malting water, except from one small malting, is taken below the town, collected in tanks, and pumped to a sewage farm situated on high land. The whole principle of a well-laid out sewage farm is here carried out; the effluent is good. Samples of the sewage flow, taken each hour of the twenty-four, showed that during about four hours of the night very little absolute impurity came down. The sewers have a very large quantity of infiltrated subsoil water, and the sewage is very weak; this being the case, and to save pumping, about four or five hours of the night flow is filtered through gravel and charcoal; all the rest is pumped daily, Sundays included, on to the farm. I have not the details of the cost of the farm, but I fear it is a heavy charge to the ratepayers.

The conclusions I have arrived at on the whole question, apart from those already expressed are, that if we are to have our rivers purified. the whole country should be mapped out into districts, each under a competent sanitary officer, who should have large powers; under conservancy boards, formed to legalize his acts. That local authorities should receive advice from head-quarters as to the most advisable means for the abatement of the nuisances of which complaint is made. That local authorities should be officially informed of the satisfaction, or otherwise, with which their efforts to abate nuisances are viewed; thus much needless cost to ratepayers might be saved, and a result sooner arrived at.

That no chemical standard of purity should be enforced, the standard to be that of common sense as suggested by Lord Salisbury, each place being bound to do its best under existing conditions.

That irrigation farms whereon sewage "pure and simple" is discharged is not a mode of disposing of sewage which

commends itself for universal adoption. The Mosaic law, 1451 years B.C., pointed to the land as the best purifier of refuse; it is so, undoubtedly, but we must remember that conditions are altered, and although the sewage may be purified by a sewage farm or a filtration ground, if passed without deodorization on to them, there is an unmistakeable odor which, healthy or not, is by no means pleasant to the senses.

All sewage, in my opinion, should be deodorized before it is applied to the land; thus our air as well as our rivers might be kept pure.

Specially in my own watershed, I think irrigation farms in the low-lying districts of the Lee Valley are particularly to be deprecated. Sewage constantly poured into a water logged stratum must in time become a nuisance. The farms at Ponder's End and Rye meads are examples. At Bishop Stortford, where the land is high, no nuisance exists, it is far from any buildings, and the smell is unimportant.

As to chemical treatment, it is easy enough to clarify, and partially purify, sewage; being only a matter of cost.

I think the experience of the last few years has shown that we must not expect to make money by manufacturing manure out of sewage; we must pay for getting rid of our refuse just as for any other necessary of life. What is wanted is, a system which shall carry out this necessity, at a cost which shall be within the reach of local bodies, and possibly within the requirements of rate-payer's associations.

I have before stated that at Edmonton and Tottenham an effluent sufficiently pure for all sanitary purposes is now discharged; there is also an absence of nuisance at the works such as I have not met with elsewhere.

I do not wish to condemn systems upon which no doubt much will be said, or to blind myself to anything in particular. The lime process and its residue were abominations. The Whitthread process, apart from the smell of the sludge and the cost, was an improvement. The Phosphate Sewage Company do not state the cost of their process, and I cannot help saying that it will be difficult to find a more efficient, harmless, and economical means of treating sewage than that introduced into my watershed by Mr. Hille; should a better system exist, I shall be only too glad to hear of it; and if in the future the Lee watershed and its sewage treatment be pointed to as a model for the country, my ambition will be fully satisfied.

SOUNDING-BOARDS.—In many large churches and halls of bad acoustic properties, where sounding-boards have been unsuccessfully introduced, the failure has been owing to the form and situation of the individual sounding-board used, and does not prove that a proper sounding-board would not remedy the defect. In a large church at Montreal, Can., which is noted for the ease with which a speaker can be heard in it, the sounding-board used is a simple horizontal ceiling of polygonal form, suspended not more than two feet above the head of the speaker. It is built of heavy oak, and projects ten or twelve feet on each side of the speaker. It is this form of sounding-board that is commonly used in cathedral churches in Europe,—churches which were not originally intended for speaking, and in which the voice would be lost in the vaults if it were not for the use of a sounding-board. In some of these churches which are provided with fixed seats and stalls, the last row of seats is provided with a strong oak partition, from the top of which projects towards the speaker a hood or sounding-board, six feet or more in depth; listeners in this back row of seats can hear much better than those in many of the seats nearer the speaker. At the New York Crystal Palace, some twenty-five years ago, an attempt was made to remedy the acoustic defect of the auditorium by the use of a horizontal sounding-board of polygonal form. That the attempt was a failure must not be attributed to the form of the sounding-board, but rather to the material of which it was composed. It was built by the Messrs. Hall & Sons, piano-makers, and the wood used was the thin and resonant wood used for making the sounding-boards of pianos; so that instead of reflecting the sound, as it was intended to do, and as heavier wood would have done, it absorbed it into its own mass, and vibrated with the air.

LEAD IN ITS RELATIONS TO WATER SUPPLY.

From "The Builder."

TREATING, some time ago, of lead in its relations to architecture, we promised to recur to the subject in connection with water supply, which is undoubtedly one of its most important aspects. In this article, accordingly, we have put together a few brief and imperfect notes on the chemical reactions of lead; and some other particulars.

The conclusion at which we had arrived was that lead is in every respect a superior roofing material to either zinc or galvanized iron. We may add copper which is still used under certain circumstance, and for these reasons: The physical qualities of lead render the *working* of it easier than of any other metal; its chemical properties supply greater resistance to the action of the atmosphere; and, lastly, being among the metals the greatest non-conductor of electricity, it affords the highest security and protection to a building during the occurrence of a lightning storm. In some cities of South America—chiefly, we believe, in Chili and Peru—where sheet copper has been extensively used as a covering for platforms as well as ordinary flushings and aprons, the copper-clad roofs have repeatedly been found highly dangerous under such circumstances. The most of them sustained severe damage; while, in fact, the slate or lead roofs escaped uninjured. Since lead is also very low in the scale or series of heat-conducting metals, it follows that there is less expansion and contraction with changes of temperature. It likewise interposes to that extent a greater barrier to the action of the sun's rays on the interior of a building. Even slates, as we all know (small "Welsh Ladies," for example), in our own climate, to go no further, sometimes render the upper stories so hot as to be almost uninhabitable; whereas a lead roof—partly, of course, owing to its greater solidity of construction—exercises a much greater modifying influence. We will not press this point, however, as we have already noticed that the great expense of lead has gradually forced us to adopt a combination of slates and lead, which, if not the noblest form of our modern roof, is still, under certain limits, the most substantial, and may be made the most picturesque. Those who have studied the drawings of the Mediæval Dutch and German cathedrals and churches which have appeared in our pages need not be indoctrinated on the latter point at least; for, although it is a pity, it is true that our highest lessons in this style of art must still be derived from Continental sources.

A good deal might still be said with regard to the artistic treatment, but we need not enlarge further upon the application of lead to roof-work. The beautiful engrailed work of some old roofs: the fish-scale work, the curious projecting gutters, the rain-water pipes, the rain-water heads, spouts, gurgoyles, and finials—all these, we are afraid, must now be consigned to the portfolio of the archæologist; since lead as a material is gradually being superseded by cast and malleable iron. For the covering of domes, cupolas, and other curved surfaces, lead is undoubtedly the proper metal; although even in these cases zinc has of late years also been applied with successful results. We may again insist here on what we previously pointed out, that lead imperatively demands the very highest skill and craftsmanship on the part of the plumber; and that it is the poorest of all economy to punish the lead-work of a roof in order perhaps to elaborate a plastered front, or add to the weight of a projecting cornice!

So much, then, with regard to lead as applied to the outside of a building. When we come to speak of its uses *inside* we must alter our eulogistic tone considerably. There can be no doubt but those physical and chemical properties we have mentioned which recommend the metal so pre-eminently for roofing and other exterior purposes also bring it to the front in the case of the interior fittings—that is to say, whenever it is intended to confine or convey water, or gas, or soil, or steam. Lead, in point of fact, occupies a foremost place in the economy of what we may briefly des-

cribe as domestic engineering. The reciprocal action of lead on copper, iron, tin, and zinc, involves questions with which the construction of every modern mansion, or building of any note, is more or less concerned. There are, for example, the *modus operandi* of hot-air pipes, hot water pipes, steam pipes, etc., in which the merely mechanical principles of junction and the relative pressure on the tubes exercise the greatest influence on the safety and stability of the building.

It is almost impossible, indeed, to fit up an ordinary system of hot-water pipes, or even a kitchen boiler with a hot-water cistern at the top of the house in which lead pipes are not in some form or other made use of, and in which these principles do not come into play. It is hardly necessary to add that the utmost carefulness is requisite in the construction, and the most constant watchfulness in the practical operation of all such apparatus. The junction of lead with iron pipes in a hot-water system is often attended with danger; on this account alone that the expansion and contraction of the two metals, as well as their chemical affinities, are unequal. We have seen, for instance a one-inch lead pipe united at right angles by a soldered joint to a malleable iron pipe, which joint burst so repeatedly and so dangerously that the iron pipe had to be cut at the junction and a triangular brass socket soldered to lead and screwed to iron. We have also observed in several large breweries, where pipes of unusual calibre are employed, that the joints of the huge brass stop-cocks with which they were furnished invariably gave way at the point where the different ratios of expansion might be supposed to converge, or even perhaps where a certain slow but sure electrical action had supervened. Another question of great importance in this connection, is the action of frost on lead pipes, which, however, we have so frequently treated, that the whole causes and consequences of this phenomenon must be familiar to our readers. We will only repeat here, in the same tone of warning that we have so often had occasion to use, that a frozen water-pipe may signify either a burst boiler in the kitchen or a deluge over the drawing-room ceiling, or both, and may often lead, and has repeatedly led, to serious and even fatal accidents.

We may as well indicate here that however useful and convenient lead may be found with regard to interior fittings there are certain purposes, we may mention, to which it may be grossly misapplied. For example, there is one domestic use to which lead should never be put to under any circumstances—that is, the lining of a kitchen sink. Those who remember the old-fashioned form of leaden sinks will recall the amount of trouble and annoyance which they gave to all good housekeepers. Constantly cracking at the bottom, or the junction of the soil-pipe, they were never thoroughly water-tight, and were thus the everlasting cause of damage from leakage. This was more particularly the case with respect to tenemented houses where the kitchen sinks overtopped each other in several stories, and where a leaky sink at the top of the house was the prolific cause of injury to the floors beneath. The introduction of iron for this purpose, and better still of stout, glazed earthenware, was a great boon to our kitchen-maids, and an improvement in our household sanitary economy. Equally obnoxious, far more so indeed, is the application of lead to urinals, and, as we have even seen, to water-closet pans, of which disgusting nuisances there are still too many in existence—particularly, as we remember, in the regions of Newcastle-upon-Tyne, and other northern towns. And the same objection applies *a fortiori* to soil-pipes of water-closets, which if not properly laid with a due inclination to the drain, and, above all things, properly ventilated, will sooner or later corrode at the joints, burst, and allow the poisonous sewer gases to escape into the atmosphere of the house, especially and most probably into the bedrooms during the night. We have, however, already touched more than once upon this startling subject, and pointed out the necessary precautions and remedies. But we may further insist here on the impropriety of that bad architectural practice—still too frequent, we are afraid—which plans a water-closet soil-pipe to be carried through lobbies and stair-landings, or even rooms; the plain consequence being, that these soil-pipes, lying at a dead

level and often improperly flushed, just constitute a permanent and seething receptacle to soil in a state of putrefaction. We may also point out an error of a similar character which is often committed, and that is the burying of a leaden pipe in a wall covered with damp plaster, or in a ground track impregnated with lime, or perhaps filled in with lime rubbish. No substance exercises a greater corroding influence on lead than lime, as some of our readers know to their cost, and this is one case where corrosion is followed by evil consequences. The strongest of all objections, however, we can have to lead is its application to the lining of cisterns and to supply-pipes, properly so called. This at once opens up one of the most serious and important questions of the sanitary economy of the present day. And although the subject may be well known, and even hackneyed, to some of our professional readers, and besides somewhat too "toxicological" for our pages, our general readers will excuse another slight discursion on account of the importance of the subject, which can never, we fear, become stale. We refer, of course, to the poisonous action of lead upon water.

The subject was first scientifically investigated in this country during the earlier half of the present century by Dr. Sir R. Christison, professor of Materia Medica in the University of Edinburgh, whose researches have been generally confirmed by Dr. Alfred Taylor, of Guy's Hospital, Dr. Dalton, of Dublin, and many other medico-legal authorities whose works we have consulted. The French toxicologists, the celebrated Orfilla and Tanquerel, generally coincide in the conclusions at which these authors have arrived; and the German analysts and physiological chemists, Muller, Liebig, Virchow, and others of that school, likewise record their adherence.

But it is very remarkable that this form of mineral poison was not unknown to the architects and physicians of antiquity. For the action of water upon lead has been the subject of observation for many ages. Vitruvius absolutely forbids the use of this metal for conducting water, because "ceruse, (*i. e.*, white lead) was formed on it; which he very properly held was hurtful to the human body. Galen also condemns the use of leaden pipes, because he was quite aware that water transmitted through such channels contracted a certain sort of *muddiness* from the lead; the consequences of which were, that those who drank such water were subject to dysentery. Indeed, if we trace, as Dr. Christison tells us, the sciences of architecture, chemistry, and medicine downwards from these periods, nothing more will be found than a repetition of the sentiments of Vitruvius and Galen but a few particular facts in support of them till we arrive at the close of the last century.

Within our brief limits it would, of course, be impossible to convey even a meagre outline of the laborious experiments and masterly inductions of these celebrated chemists; but the following *resumé* may help, perhaps, to make the subject more intelligible.

In order to ascertain the true chemical action of lead upon water, we must first of all look to the action of lead upon air. Whenever a fresh-cut surface of lead is exposed to the air it gets tarnished, a circumstance which is due to the strong affinity of the metal for oxygen. There arises a thin coating of the hydrated oxyd of lead, which is easily transformed to the *carbonate*, which again seems to form the permanent crust. The opinion which many persons entertain that the hard crust of lead is a mere deposit of its oxyd, is therefore incorrect. If lead were to oxydize continuously by contact with air —like a particle of sodium in a basin of water—we should have very little indeed to say of its history, and still less, we are afraid, of its architectural relations. The formation of the carbonate of lead is always accelerated by moisture, and probably by the presence of an unusual proportion of carbonic acid in the atmosphere; but, not to enter into minutiæ, in whatsoever way it may be formed this carbonate of lead, in all its forms and combinations, is a deadly poison.

When water passes through leaden pipes, or is stored in a leaden cistern, a similar chemical reaction occurs. Water, which is composed of oxygen and hydrogen, and almost invariably charged with carbonic acid, plays the same part,

mutatis mutandis, in the process that air does, with this additional and aggravating circumstance that water *dissolves* the carbonate (which of course the air, or at least the dry air, cannot do), and according to the nature, extent, and duration of the necessary conditions holds this poison in solution.

These conditions, however, are so modified by a wise provision of nature that in the vast bulk of our natural supplies of water the antidote to the poison accompanies it and neutralizes it. Whenever water contains lime, soda, potash, or other mineral salt, it deposits a crust of that salt on the surface of the lead in the form of *an insoluble carbonate;* and so protects its surface from the chemical action which invariably occurs when the water is pure. The conclusion at which we arrive here accordingly is a fact which should always hold a prominent place in our sanitary aphorisms :— *The purer the water the greater the danger of lead poison.* We will not enter upon the wide topic of the physiological influences of the poison. We need only mention that the symptoms which follow are first of all "lead colic," which is by far the most frequent form of disease; secondly, "lead rheumatism"; thirdly, "lead palsy or paralysis"; and finally, "disease of the brain," which is the least common, but the saddest of all the forms of lead poisoning. It is also proper to point out that the poison may be introduced into the system by being *absorbed* through the skin, and *inhaled* through the lungs, as well as being *imbibed* by the stomach; and with two or three short illustrations of these separate classes we will conclude our exposition.

1. In the first place, with regard to the poison entering the system through the stomach a whole catalogue of cases may be found in the authorities we have cited. It is, perhaps, sufficient to recall to the recollection of our readers the celebrated case of the ex-Royal Family of France during their residence at Claremont, of which full details (of that and numerous others) will be found in Dr. Taylor's work.

The water at Claremont was of exceptional purity; it acted on the leaden pipes, and the result was that no less than *thirteen* persons were attacked with severe colic (including several members of the Royal Family), and, as far as we remember, two of the grooms died. Dr. Christison mentions a similar case which occurred at a gentleman's residence at Dumfriesshire, whose family were constantly ill, and to whom his professional services were called in. He immediately discovered symptoms of lead-poisoning, which led him to examine the water; and he actually discovered that the lead supply-pipe, nearly a mile in length, which conducted the water from a very pure spring (proceeding out of rock, by the way) to the house was almost corroded to nothing throughout its entire length! We will explain presently what Dr. Christison did to avert the evil; but we may mention a case here, on the same authority, which is no doubt still common enough; and that is where a series of water-barrels, at a country house, fitted up to collect and store the rain water from the roof, which had been newly covered with a lead platform, gutters, and ridges, became so impregnated with lead that the whole family suffered from severe colic in consequence. We may add also that the danger is not confined to leaden pipes and cisterns, with their corresponding apparatus of water supply. It exists to a large extent in our ordinary cooking utensils! That vile practice, as Dr. Taylor justly calls it, which has sprang up of late years of substituting for pure block tin an alloy of tin and lead in the lining of our cast iron pots is an extremely dangerous one, as we have before pointed out, and calls loudly for the sternest repression. And not only metallic pots, but earthenware vessels are also liable to the same fatal objection, simply arising from their *glaze*, which is always composed of lead in some form. Vinegar, or pickles, or any acid solution will produce the acetate of lead when preserved in such a vessel. Everybody knows, or ought to know, that boiling fat will melt and even dissolve lead; and cases are on record, such as a whole family being nearly poisoned, from eating the fat or dripping of meat which had been baked in a newly-glazed earthenware dish. The whole of this subject, which we cannot at this moment pursue further, has recently been investigated with great ability by a modern French chemist, Monsieur Gobez; and our readers who wish to arrive at the

newest and most authentic conclusions with respect to the poisons of lead introduced into the system through the stomach should consult that author's valuable papers, which are published in the *Annales de Hygiene* for the year 1869.

2. Our second division relates to the process of absorbing the poison through the skin. The commonest form of the disease in this case is "painter's colic," which is certainly also one of the worst forms of the chronic poisoning of lead. Dr. Taylor gives numerous instances of the baleful effects of lead on the systems of lead-smelters, white-lead workers, painters, and even plumbers. We have often recorded and described such cases, and need not repeat them. The symptoms are unfortunately too well known, and are described with great minuteness in most of the dictionaries and encyclopedias, under the head of "Lead Palsy" or "Paralysis." We may add here that lead is more injurious to the system than other metallic compounds, on account of its being a *cumulative* as well as an irritant poison.

3. But lead colic and paralysis may also be produced by inhalation; hence our next division relates to the absorption of lead through the lungs. Not painters and lead workers alone suffer from this insidious cause; but every symptom of the disease has been known to occur in the case of persons who have, for example, slept in newly painted rooms, "I have, myself," says Dr. Taylor, "suffered from a severe attack of colic as a result of sitting in a room, for a few hours a day, in which a large surface of canvas for an oil painting had been covered with white lead and drying oil." Another case mentioned by the same authority is that of a military officer, who was fond of painting in oil colors, and who worked for some time in a studio eight feet square, which had a large stove in it. The consequences were that he was attacked with "wrist-drop," and soon afterwards with paralysis in both legs. His servant, who ground his colors and washed his brushes, had also a severe attack. "In these instances," continues Dr. Taylor, "the emanations of lead must have reached the blood through the lungs; although chemists may doubtless be found who will prove by ingeniously devised experiments that there could be no lead in the air of the room; and who—coupling their results with the fact that few artists are known to suffer from such symptoms—will therefore contend that lead was not the cause. The symptoms, however were of that character which is peculiar to lead poisoning; and as the insidious effects completely disappeared on the removal of the patient to another atmosphere, I think there could have been no doubt whatever about the cause."

It follows from all this that the atmosphere of a room tainted or impregnated with lead is as dangerous as the well-known poisonous atmosphere induced by the celebrated green flock and gold papers which we have so often denounced, the coloring basis of which was found in numerous cases to be arsenic.

Having said so much about the poison of lead, it now remains that we should add something concerning the remedies; but here we must necessarily be very brief. It is not our business, of course, to grapple with the therapeutics of the subject; for the treatment of the disease we have mentioned belong to the province of the physician. Our vocation—not less important, as we hold,—with regard to this and similar subjects lies more in the direction of *prevention* than of cure. Nevertheless, since we are treading as it were on the very threshold of the subject, we may venture to interpose a few words on behalf of suffering humanity.

First of all let us say a single word with regard to its *detection*. To discover the fumes of carbonate of lead in the atmosphere of a room is rather a difficult and delicate operation (although perfectly certain and reliable), but the detection of its solution in water is one of the simpliest process in the whole range of analytical chemistry. We cannot go into details: it may be enough to say that with the simple apparatus of a watch-glass and a test-tube, together with a few drops of hydrochloric acid and of sulphuretted hydrogen in solution, it is quite sufficient to detect even the thousandth part of a grain in a gallon of water.

The symptoms in the human system are also easy of diagnosis or *distinguishment;* and it is only necessary that we should state here that the treatment of the disease in its various stages is entitled

to rank amongst the greatest triumphs of our medical practice in the present century. Sulphur, surphuric acid, sulphate of soda, sulphate of magnesia, sulphuretted baths, sulphur in some form or other, it is curious to know, is the grand antidote to the poison of lead. Its action, of course, like that of any other antidote, is to neutralize the active influences of the poison in the blood.

But the real fact of the matter is that preventive measures are, after all, the most beneficial; and exercise the most potent and potential influences for good. For example, in the case of white lead manufacturers, where the poison enters the system chiefly through the skin, it had been found that *personal cleanliness* exercises a surprising effect on the health of the operatives. Painters, plumbers, lead-smelters, and other artisans who neglect to wash their hands before meals, little know the damage they are doing to their constitutions. Indeed, to give a specific instance, there was a large and celebrated *plomb-blanc* manufactory in the South of France, which was at one time notorious for its lead palsy. The proprietors, acting under the highest medical advice from Paris, at length adopted and rigorously enforced a system of sanitary precautions, which eventually put a stop to the disease, and very nearly extirpated it altogether! These measures were simple enough, and ought to be widely known. In the first place, the workmen were compelled at every meal-hour to wash their hands in hot water and potash, and also to *use the nail-brush*. Secondly, they had hot or tepid baths every evening before leaving the works. In the third place, a frequent change of clean *linen* garments was supplied to them; and finally, some supervision was exercised over the lead-worker's food, and the condition of their homes.

The laws of prevention,—which are more in our way, as we have hinted,—also operate quite as vigorously in the case of the lead poisons being inhaled through the lungs. In the particular instance quoted above of the officer's studio, ventilation immediately suggests itself as the most thorough-going and effectual remedy. We will not speak of the size of the room,—(eight feet square!), which must be nearly incredible to persons who do not reside in London, and is certainly discreditable to the officer's common sense, and for this simple reason, that any size of room under the same conditions may have had its atmosphere poisoned, burnt up, and destroyed in a similar fashion. Given a hot stove, closed windows, a street-door, a blocked-up chimney-place, plenty of white lead and oil of turpentine, two or three argand gas-burners, and two or three pairs of human lungs, and it needs no ghost come from the grave to tell us the result of the problem. The Black-hole in Calcutta was hardly so bad. On the other hand, give us an open fire-place and two or three of Arnot's valves, or Banner's ventilators, or a system of hot-water pipes, or hot air entering from the surbase, and passing through the cornice of the ceiling, or a movable skylight hung on pulleys, or, in short, any method whatsoever (and the simpler the better) of providing an ever-changing supply of fresh air, and we will "stake our critical sagacity," as Lord Jeffrey used to say, that there will be no lead palsy or paralysis superinduced in such an apartment. As to artists, as a class, not suffering from the effects of lead paint, we are not so sure of that as Dr. Taylor seems to be. The symptoms of lead colic we are assured are frequent enough; and even palsy is not uncommon. Indeed, we have no hesitation in saying (and we speak from long experience, and extensive observation) that many a hard-working artist in oil colors,—particularly those who work much by gas-light,—has his valuable life abridged, and his days shortened, by the vile atmosphere of his studio. We ought to mention here that water-colors are, of course, quite innocuous in their handling; and although the idea is rather of a comical character, we have heard it repeatedly asserted that smoking tobacco, which most artists do in inordinate quantity, is also preventive or remedial of a poisoned atmosphere! We would not, however, stake our sagacity on this knotty point, unless we were in a position to prove (which, as at present advised, we are not) that a *narcotic* poison is counteractive of an *irritant* one.

When we revert to the poison introduced into the system through the stomach, we shall find the same beneficent

principles still hold good. We have mentioned, in the case of leaden supply-pipes and water-cisterns, that Nature, herself, in the vast bulk of potable waters, provides the remedy in the form of depositing over the surface of the lead an insoluble salt, most commonly a carbonate of lime. In the case at Dumfriesshire, where, as we have mentioned, Dr. Christison was called in, that eminent physician skillfully availed himself of this natural law to counteract the action of the water on the leaden supply-pipe, which conducting a very pure spring, was nearly eaten away. He had a new supply-pipe laid down, filled with water, and corked up at both ends for several months until the insoluble coating was deposited so thick that no danger could be apprehended. But this case occurred thirty years ago, and since then we have had the invention of coating leaden pipes over their inside surface with block tin, —a metal which, it is well known, has no poisonous re-actions; though objections of another kind have been taken to the arrangement. Such tinned lead pipes have, we believe, been laid down at Claremont and many other mansions throughout the country where the necessity for their application was found to exist, and always, we are informed, with the most successful results.

There are various reasons also in operation at this moment which render the use of leaden supply-pipes more dangerous than it was before. The most important of these, perhaps, is the additional quantity of lake water we are bringing into use (as in Glasgow), and of rain water which we are compelled to store (as in Edinburgh). Both of these waters are pre-eminently pure; and the evil consequences we have sufficiently indicated. Thirty years ago the Edinburgh and Glasgow waters contained sufficient mineral salts to render their passage through lead pipes quite innocuous. But we question very gravely whether this can be said at the present moment. Commending the subject to the consideration of the able public analysists of both cities, we will only further remark that sooner or later lead in all its forms must be removed altogether from the regions of our water supply. It contains most unquestionably a constant and most serious element of danger. Iron, tin, zinc, earthenware, concrete (why not?), vulcanite, or even, as Vitruvius suggested, *leather!*—each and all of these are better than lead. None, of course, are so easy to work as lead; but our plumbers must learn to march with the times, and rise to the occasion, or otherwise we are afraid another race of mechanics will gradually supersede them in relation to the public health.

REPORTS OF ENGINEERING SOCIETIES.

Scottish Society of Arts.—At a meeting of this society, held in Edinburgh, Mr. John Milne, president, in the chair, Mr. D. B. Peebles read a paper on "Peebles' Patent Governors for Stations, Districts, Dwelling-houses and Public Lamps." In the course of his remarks the reader showed that when once a gas-governor was adjusted to deliver gas at a given pressure it maintained that pressure under all variations, and also under all differences in the rate of consumption. He explained, with regard to the gas-governors of his own invention, that the bell or holder was entirely inclosed in a gas-tight case, so that an accident from any escape of gas was rendered an impossibility. The bell worked freely in the case, being guided by a set of four pulleys at top and bottom. A valve was suspended from the dome, and the arrangement of the pipe was similar to that of governors which had been long in use. Abandoning the parabolic valve at present employed in all station governors, Mr. Peebles substituted a spherical valve, to which was attached a parallel cylindrical body with a conical bottom working a vessel having communication with the water contained in the outer case.

Highland Agricultural Society.—At a meeting of the above society, held in Edinburgh, a report was submitted on a trial of potato-planters which took place on the farm of Liberton Mains, on 4th April last. The committee stated that six machines appeared on the ground exhibited by (1) Mr. Dewar, Kellas, Dundee; (2) Alexander Guthrie Craigs, Montrose; (3) Chas. Hay, North Merchiston, Edinburgh; (4) G. W. Murray and Co., Banff (Ferguson's patent); (5 and 6) J. W. Robinson and Co., Liverpool (Aspinwall's patent). The committee reported generally that the machines were greatly improved since the trial in October last, and, with the exception of Aspinwall's machine, which appeared for the first time, they attributed that improvement very much to the trial formerly held. They believed that all the machines would have done their work well with whole seed riddled to one size, but on this occasion they were put to a thorough test, being tried with seed of all sizes, both cut and uncut. After a thorough trial the committee selected three machines, viz., Mr. Guthrie's, Messrs. Murray and Co's, and Aspinwall's patent, and again subjected them to a further trial, each machine being drawn by the same horses. The committee recommended

the directors to award a £10 prize to Mr. Guthrie for a double-drill potato-planter on the cup principle, and a similar prize of £10 to Messrs. J. W. Robinson and Co., Liverpool, for Aspinwall's patent single drill potato-planter, on the needle principle.

EDINBURGH AND LEITH ENGINEERS' SOCIETY.—At a meeting of this society, Mr. John Buchanan presiding, a paper on "Creosoted Timber" was read by Mr. C. Graham Smith. Having touched on the chemistry of creosote oil, the writer passed on to describe in detail the process and plant which were necessary in the creosoting of timber. Before commencing the process, all sapwood should be removed, and such timber should be selected as was dry and well seasoned. Unless this precaution were taken, the oil would only penetrate the wood to a very small depth below the surface, and by confining the water and sap in the interior, would thus render the wood liable to rapid internal decay, as was the case when wood, imperfectly seasoned, was painted or tarred. The writer next noticed the difference in the time required to creosote the various descriptions of wood and the difference in the quantity of oil which each could absorb. For instance: yellow pine might easily be impregnated with twelve pounds of creosote per cubic foot; Baltic with ten pounds; while denser timber, such as pitch-pine or oak, could not be made to absorb half that quantity. Various facts and observations were afterwards submitted, with a view to show that the process of creosoting to a great extent preserved timber from the ravages of worms, although for what particular length of time, was a question which required more extended observation to determine. Mr. Smith proceeded to describe a series of experiments which he had made, in order to ascertain the inflammability of creosoted timber, and which had led to the conclusion that though creosoted timber was considerably more "combustible" than wood, which had not undergone the process, the former was very little more "inflammable."

SOCIETY OF ENGINEERS—VENTILATION.—At a meeting of the Society of Civil Engineers, held on the 1st of May, the first paper read was "On Flues and Ventilation," by Mr. A. H. C. Trewman.

The second paper read was "On the Ventilation of Buildings," by Mr. J. W. Pearse, and in which the author described some of the leading appliances for that purpose. He first referred to the vertical system of ventilation revived by Mr. Tobin, in which fresh air is admitted into the room by vertical pipes communicating with the outer air and reaching nearly to the ceiling. In this system holes or slots in the lower rail of the upper window-sash are, in some cases, substituted for the vertical pipes. Mr. James Livesey, the author observed, purified the air before allowing it to enter the room, by causing it to be deflected on to the surface of a tray of water, which also had the effect of cooling it. Mr. John Currall, in his system, makes an aperture in the lower part of the window for the admission of fresh air, and another in the upper part for the escape of foul air. When there is a chimney in the room he introduces the fresh air by an aperture in the lower part of the door, and takes off the vitiated air by a ventilator in the chimney breast. Mr. M. J. Landau has designed a ventilating cowl, terminating at the top in a series of horizontal annular plates. The wind blowing across the plates induces a current up the shaft. Fresh air is admitted by a horizontal pipe closed at the outer end, but provided with annular plates and fixed in an outer wall. For extracting foul air from buildings or drains, Mr. E. G. Banner has invented a swiveling cowl, which has a bell-mouth, and is always directed towards the wind by a vane. The shaft is continued by a bend inside the tail of the cowl and swiveling with it. There is an annular space between the two tubes in which the air entering the bell-mouth is compressed, its subsequent expansion inducing a current up the shaft.

THE INSTITUTION OF CIVIL ENGINEERS.—At a meeting on the 2d of May, the paper read was on "Fascine Works at the Outfalls of the Fen Rivers, and Reclamation of the Foreshore," by Mr. W. H. Wheeler, C. E.

It was stated that the four rivers which take the drainage of the Fens of Lincolnshire and Cambridgeshire, and the lands bordering thereon, discharged into an estuary filled with large beds of shifting sands, and that in order to secure an outfall for these rivers it had been necessary to train their channels through the sands. The most economical way of accomplishing this had been by means of training walls, constructed of fascines and clay and chalk. Very beneficial results had followed from this training and straightening of the outfalls, and the low-water mark had been lowered several feet. The advantage of confining the rivers to one course was shown by the fact that when in the trained portion of the channels there was a depth of ten feet at low-water, below it there would be a depth of only from two feet to three feet. The faggots used for building the training walls or jetties were made from thorns cut from the hedges, tied together with tarred string. The length of each faggot was six feet, and its girth three feet. These were thrown into the water from barges and weighted with clay, layer after layer being thus placed, until the jetty was brought up to half-tide level. The depth of water in which these jetties had been built varied from ten feet to twenty feet, the top being about six feet above low-water. The base of a jetty sixteen feet high was twenty-two feet wide, and the top thirteen feet. The cost per lineal foot for the work done on the Witham averaged 19s. 3d., or 1s. 8d. per cubic yard, the details of which were given. The thorns and clay together formed such a compact mass, that the jetty was able to withstand the force of both the ebb and tidal currents, and was a cheap and effective means of carrying out the training of these rivers.

After the formation of the jetties, the sand and silt accumulated at the back, and ultimately grew into green marsh. The accretion of land was gradually taking place all along the

foreshore of the Wash, but to a much greater extent on the Lincolnshire than on the Norfolk coast. The process of accretion was very slow, unless assisted by artificial means. A marsh, under favorable circumstances, would reach a stage fit for enclosure in about thirty-five or forty years. The process of accretion might be hastened by placing faggots across the foreshore to break the force of the water and so assist in the deposit of warp, and by inoculating the ground with sods cut from the adjoining marshes. The value of the salt marshes for feeding sheep before enclosure was from 5s. to 6s. an acre, and the value of the freehold £20. The cost of enclosure was from £15 to £20 an acre, and the value of the land after enclosure from £50 to £60.

IRON AND STEEL NOTES.

USE OF RAIL ENDS IN BLAST FURNACES.—According to Heyrowsky, it has been found, at Zeltweg, very advantageous to add the crop ends from the rail mill to the charge on the blast furnace, and at present, from this reason, the blast furnace at Zeltweg, which formerly only produced 230 tons of gray Bessemer pig iron per week, now turns out 270, the increase of the forty tons in the make corresponding exactly to the quantity of rail ends added to the charge.

BLOWN CAST IRON.—From the *Moniteur des Interets Materiels*, for the 28th November, 1875, we learn that considerable attention has been given of late, in Belgium, to a method for, to some degree, refining cast iron previous to puddling, put in practice by M. Fernand Hamoir, of Maubeuge. The process consists of submitting the cast iron, at the instant it is tapped from the blast furnace, to a current of air from the same blast that is being supplied to the tuyeres of the furnace itself; the process is very rapid, and the apparatus simple and inexpensive, while the advantage obtained is, that the pig iron is so far refined that one charge more per twenty-four hours can be worked in the puddling furnace.

THIN IRON.—Some exceedingly thin iron sheets have just been rolled at the works of the Pearson and Knowles Coal and Iron Company, at Warrington. They are stated to be no more than 0.0015 in. thick, and the specimen forwarded to the *Mining Journal* office is about two in. by one and a-half in., and has but four very small holes in it. The peculiarity is that Mr. Hooper, the energetic manager of the works, rolls the sheets from iron produced, from the pig to the rolled sheet, at the Company's Dallam and Bewsey forges, by a process devised by himself, and which permits of the sheets being rolled several at once, and without sticking. The iron must be of excellent quality to permit of such thin sheets being rolled at all.

RAILWAY NOTES.

TILP'S LOCKING BOLT.—Owing to several concurring causes—imperfections in the permanent way, imperfect balancing of the moving parts, and the effect of the working of the engine—locomotives in action are liable to an inconvenient and even dangerous amount of lateral oscillation, technically known as shouldering. To reduce this action to its least possible limits, Mr. Emil Tilp has invented an apparatus already extensively adopted throughout the Continent, and for which Mr. Henry Simon, of Manchester, is the English agent. Mr. Tilp's plan, in brief, consists in locking together the contiguous ends of the engine and tender by means of a locking bolt, so arranged that when they pass on to a curve the locking bolt is automatically withdrawn, the engine, and tender being thus allowed to assume the requisite angular position. This bolt, which is made of suitable strength, is fixed on the end of the tender framing next the engine, passing through a guide on the framing. The head of the bolt has bevel side faces, and fits into a recess having correspondingly beveled faces formed in a strong boss fixed on the trailing buffer-plate of the engine. The bolt is acted upon at its inner end by a strong spring tending to keep it engaged in the recess in the boss just mentioned, a screwed collar being provided on it, against which the spring bears, and by adjusting which the pressure of the spring may be regulated. The bolt is furthermore linked to the ends of two levers extending horizontally on each side of it towards the side framing of the tender, to which their other ends are linked. At intermediate points of their length these levers are made to bear against strong pins passing through guides in the end framing of the tender, and bearing against the end framing of the engine at some distance apart, on each side of the before-mentioned locking bolt. From this description it will be understood that as long as the longitudinal axes of engine and tender are in a line they will be locked together and lateral motion prevented. On the other hand, when the engine and tender pass from a straight line on to a curve, the end faces of the engine and the tender framing in approaching each other on one side of the locking bolt, due to the angle formed between them, will cause one of the before-mentioned pins to be forced inwards, whereby the corresponding lever will be forced back, and will thus be made to withdraw the locking bolt as far as necessary from the recess on the engine. —*Iron.*

RAILWAY SIGNALS AND BLOCKS.—The Highland Railway of Scotland has introduced upon its road what the English journals describe as a novel and ingenious combined block and signal system, the invention of Dr. Whyte, who has devoted several years to the work of improving the mechanical arrangements for operating railway trains. The system is entirely self-acting, and its operations are performed with the agency of an electro-magnetic machine of simple construction. An engine running past, say two stations, blocks the line at the first by raising a semaphore; places an automatic check against the passing of a second engine by the ringing of an alarm bell on the second engine itself, should it attempt to follow; announces its approach to the second

station, or can be stopped by the station-master there; while on reaching that station, it clears the line at the previous one of both semaphore and alarm bell, so as to leave it free for any approaching train. The apparatus itself may be divided into two parts, one being on the engine and the other connected with the line. Four wire brushes, each pair mechanically connected, are suspended from the engine, one pair having a battery and bell in circuit, and the other a bell. A wheel descends alongside these brushes. On the line, between the rails, at such distances as may be thought requisite, or in close proximity to each station, a series of insulated metallic plates, in an air-tight box, are laid down, each plate being from five to ten feet long. By the side of each pair of plates, the ends of which are connected by wires, is placed an electro-magnet, with wires from a battery attached. The keeper of the magnet is fixed to a lever by means of a pulley, and as the engine travels past, this lever is pressed upon by the wheel above mentioned, and the keeper is forced up against the poles of the magnet. Thus the semaphore arm is raised and the line effectually blocked. With the view, however, to guard against a possible inattention on the part of the driver of an engine approaching the apparatus, the box is left in such a position that should his engine pass over it while the signal is up the alarm bell on the engine itself is instantly rung. The first engine having successfully blocked the line in the rear, proceeds to the next station or signal post, where the line is again blocked; and by means of wires to the last box and mechanism similar to that above described, the electro-magnet at the former station is released, the semaphore lowered, and the way left clear between these two sections. Thus it is clear that each train protects its rear for the distance between each pair of plates. The line being, as it were, divided into sections, each train as it enters a section instantly blocks it so that no other train can follow until the first has proceeded, without the bell being rung as a warning. Connected with this automatic electrical block system is an arrangement by which each train can announce its approach to any station, and another for giving the station-master the power to stop a train by causing the bell on the engine to ring. The brushes on the engine are the means by which this is accomplished; a powerful battery placed at one station, or smaller batteries placed in suitable positions along the line, being the agency by which the apparatus is operated. As these batteries are never in circuit except when a train works them, the waste is reduced to a minimum. The advantages claimed for this system are that, being self-acting, it entirely dispenses with manual labor, which at some critical moment is apt to be at fault; that its certainty of instantaneous action is secured by the concealment of its working parts, and their protection from wet and dust, and finally that the expense of application is comparatively small.

ENGINEERING STRUCTURES.

East River Bridge.—The Chrome Steel Company, Brooklyn, have obtained the contract to furnish the steel and iron ropes required for the erection of the temporary foot bridge, cradle cables and other appliances necessary for the construction of the main cables of the East River Bridge. The ropes will be furnished as required in the following order: First, four working ropes for pulling over wires, each rope to be 3,800 feet long, and of a breaking strength of not less than eighteen tons. Second, a carrier rope of 3,710 feet, and a breaking strength of not less than sixty tons. Third, three cradle ropes of 3,625 feet in length, and a breaking strength of not less than 180 tons. Fourth, two foot bridge ropes of 3,625 and 3,688 feet long respectively, and a breaking strength of not less than 240 tons. Fifth, the under floor guys and suspenders of an aggregate length of 10,868 feet. Sixth, the handrail ropes of a length of 3,500 feet. Seventh, the four pendulum ropes for separating strands of a length of 3,700 feet each.

The St. Gothard Tunnel.—A highly interesting paper on the mechanical arrangements for the driving of the tunnel of the Gothard was read before the Swiss Society of Natural Sciences, at their meeting at Andermatt, by Prof. D. Colladon, the consulting engineer of the enterprise, in which he remarks that the St. Gothard Tunnel has no comparable precedents but those of Mont. Cenis, completed in 1871, and of Hoosac, in the United States, finished in 1874. The Mont Cenis Tunnel, 12,233 meters in length, undertaken by eminent engineers at the cost of the Sardinian Government, and in the construction of which no useful expense was spared, required thirteen and a half years for its completion. At Hoosac, where the total length was 7,634 meters, the average progress even in later years was below that attained at Mont Cenis. For the Hoosac Tunnel the cost per running meter was over 6100 frs. The St. Gothard Tunnel, driven in harder rocks, and 14,920 meters long, is in course of construction by a Swiss Company, and according to the contracts must be completed in eight years, or in nine years at the utmost. Considering the extra length, and the shorter time allowed, the driving ought to go on twice as quickly as that of Mont Cenis. Now, can this St. Gothard Tunnel be finished in eight or nine years? is a question which properly preoccupies the industrial world. This leading question of time is connected with that of the mode of execution, and with some technical principles upon which engineers are far from being in accord. A tunnel for a double line, like that of the Frejus or the Gothard, necessitates an excavation eight meters wide and six meters high, exclusive of the space for the masonry. The whole of this large section, however, is not opened simultaneously, but only a small level—the gallerie d'advancement or de direction—about 2.40 meters high and 2.60 meters wide, which is always kept about 200 or 250 meters ahead of the enlarged portion. This small heading is driven by means of machines worked by compressed air, which furnishes both motive power and ventilation according to the system proposed by Prof Colladon in 1852 for the Mont Cenis.

The rock-drills, originally invented by Bartlett in 1855, modified and improved by the celebrated Sommeiller in 1857, are greatly multiplied and improved, and at the present time there are twenty or twenty-five different systems of these apparatus. Now, ought the advance heading to be driven at the top or at the bottom of the large section? Both methods have their partisans, more or less exclusive. The Mont Cenis Tunnel was commenced at the bottom; in the Hoosac Tunnel both systems were tried. For the St. Gothard Mr. Favre preferred the advance heading at the top; he, moreover, employs mechanical drills both for the advance headings and the enlargements—the speed with which the work has progressed shows the value of his method. A memoir on the comparative advantages of the two systems, by Mr. J. Kauffmann, and which is decidedly in favor of Mr. Favre's system, is well worth perusal. The advance heading, then, has a section of six or seven square meters. As the whole tunnel will be lined, there must further be excavated the space for the masonry, so that the roof of the advance heading will be 6.50 or 7 meters above the future level of the rails. It will be understood that in the work of driving with powder or dynamite, the several stalls where the rock is blown out cannot be worked too nearly together without perpetual danger to the sub-engineers and workmen; the excavations are, therefore, carried on at the distances necessary to insure security for the men and apparatus. The end of the advance heading—the forebreast or face—is 200 or 250 meters in advance of the place where the "*abattages*" are made for putting in the masonry roof. Again, at 200 or 300 meters behind the *abattages* they make another working underhand, called the "*cunette du strosse*," which is wrought down to the level of the future tunnel—that is to say, four or five meters below the level of the floor of the advance heading; its width is about three meters. In the same way behind the face of the *cunette* they excavate the lateral portion, which is called the *strosse*, and when the strosse is excavated they have the whole section opened, and the masonry is put in. The abattages and the advance heading are furnished with a tramway, and a tramway is also laid on the floor of the cunette. Numerous wagons are moving about incessantly on these railways, carrying in tools and materials, and bringing out the attle.

It is an incontestable axiom that the faster the advance heading progresses the more rapidly can the entire tunnel be completed. For, in the forebreast the rock being altogether in the solid, the blasting takes less effect, and moreover but few machines and few men can be employed, whilst in the enlargement more machines can be put in and incomparably more men. The progress made at the forebreast by Mr. Favre and his engineers may, without exaggeration, be described as marvelous, especially when compared with what had previously been done in rocks of similar character. Will this rate of speed be maintained? It may safely be believed that it will, since at Mont Cenis the progressive improvement in the speed continued to the end. During the last three years, 1868, 1869, 1870, the forebreast advanced 1,320, 1,431, 1,635 meters respectively. These last figures would give 409 meters as the maximum reached at the Frejus in any three months during the thirteen years it was in course of construction. At Hoosac (Massachusetts), although they employed nitroglycerine and faster drills than those of Mont Cenis, the three-monthly progress for the later years, for both ends combined, was but 207 meters in 1870, 238 meters in 1871, and 237 meters in 1872. But what has been the progress for the last five quarters at the Gothard? During the quarter ending Oct. 1, 1874.—Goeschenen end, 321.60 meters; Airolo end, 174.10 meters, together 495.70 meters. Quarter ending Jan. 1, 1875.—Goeschenen, 283.60 meters; Airolo, 243.30 meters=526.90 meters. Quarter ending April 1, 1875.—Goeschenen, 267.90 meters; Airolo, 289.10=557.00 meters. Quarter ending July 1, 1875.—Goeschenen, 312.10 meters; Airolo, 344.20=656.30. And during the quarter ending Oct. 1, 1875.—Goeschenen, 360.90 meters; Airolo, 326.20 meters, together 687.10 meters. This latter rate would permit of the construction of the entire tunnel from end to end in less than five and a-half years. The prophets have declared that Mr. Favre, impeded by the excessive hardness of the rocks, and by a much greater quantity of water than was met with either at Frejus or at Mount Hoosac, could not in any case exceed the average of three meters per day at each forebreast—that is 550 per three months for both ends. During the last three quarters this predicted maximum has become the minimum. The two last have given 3.60 meters and 3.80 meters average daily progress at each forebreast. And in this period, moreover, there were some lost days for the verification of the alignment and the momentary strike at Goeschenen.

In spite of this eminent success malevolence has not been killed. It is predicted afresh that the tunnel will not be finished in eight years, because the total cube already extracted is insufficient, and so on. In the first place, it is not eight years but nine years that is allowed by the contracts, with enormous fines it is true, but this is certainly the limit which should be referred to, and when a contractor is securing for a company 15,000,000 frs. he is at least entitled to the greatest courtesy both from the members of the company and from the workmen, especially after having achieved a success which already reflects great honor upon Switzerland. It is evident that progress in works without precedent, and where all difficulties seemed to be accumulated, must result from experimental trials, surveys, and successive improvements, and that this progress cannot be effected in a few months, nor even in a single year. The works at Mont Cenis, where expense was little thought of, and where each kilometer driven cost double that of the Gothard, proved it, since up to the last year of the working the engineers and contractors of the Frejus made improvements both in the machinery and the organization of the work. Mr. Favre has had to consider before everything the pushing forward of the forebreast.

In three years he has succeeded beyond the most sanguine expectations, thanks to his activity, energy, ingenuity, and enormous sacrifices. To-day, doubt is only expressed whether the enlargement can be carried on with equal rapidity, and upon this point it may be hoped that when the improvements in progress and those projected shall have had time to be completed, experience will prove that the fears entertained with regard to the promises of the very able contractor were premature and unjust.

ORDNANCE AND NAVAL.

EGERTON'S CHANNEL FERRY AND CATTLE SHIP.—Some time ago we described in *Iron* the very ingenious Channel Steam Ferry, designed by the late Mr. Evan Leigh, of Manchester, and still later made a brief mention of a vessel devised for a similar purpose by Mr. Hugh A. Egerton. Lately we had an opportunity of witnessing a trial of Mr. Egerton's model on the lake at the Welsh Harp, Hendon, and as the same model will be exhibited shortly on the Serpentine, the present appears an opportune time for giving some fuller account of the inventor's proposal.

The first idea we shall mention is not new. It is, to carry whole trains across the Channel in a specially constructed vessel. Mr. Egerton's notion is the eminently comfortable one, that a traveler to Paris should take his seat at Victoria or Charing Cross, and retain it till he reaches Paris or any other station at which he desires to alight. He is not alone in so exalting the merits of comfortable traveling, as to suppose that the number of persons who would cross the Channel would be at once trebled if some such method of abridging the horrors of the middle passage could be carried into practice. The vessel he suggests is of an immense breadth of beam, being, in fact, 228 feet wide and 600 feet in length. This is, in truth, as he admits, quite a monster in naval construction, though possibly no more a monstrosity than the circular ironclads upon which Mr. Reed has lately set his heart. At any rate, it rivals them in stability, and the most qualmish of travelers need not fear any derangement of the stomach. Mr. Reed's experience in this direction on the *Popoffka* supports Mr. Egerton's statement, that it is next to impossible for a passenger on his Leviathan (so to call it) to be sea-sick. This would be an important consideration to the 1,500 passengers in fifty railway carriages which he proposes to carry on his decks, and the freedom from pitching and rolling would be no less important a matter to the consignors of the parcels in his sixty loaded goods trucks.

The chief peculiarities of the construction of the Leviathan will be best introduced by the inventor's own very lucid statement of the principle upon which she is designed. This is briefly, that the size of a floating body must be adapted to the waves it is intended to encounter, if freedom from vertical motion is desired. This is very plainly explained by the following extract:

"Put a small boat in a breeze off Woolwich, and she will pitch and roll quite sufficiently to make a nervous landsman unhappy; but the sailing barge passing by at the same time will not have the least rocking motion. Place the sailing barge off the Nore in half a gale of wind, and she will imitate the small boat at Woolwich; but the large emigrant vessel just being towed out will be unaffected by such waves. Let the emigrant vessel be off Plymouth, with a heavy sea on, and she will pitch like the barge at the Nore and the small boat at Woolwich; but the *Great Eastern* in the same position, with the wind dead ahead, will be as steady as a rock, and yet the *Great Eastern* would dip her nose into the water in a gale off 'the Horn;' and any ship in existence, built on the present system, will roll with very slight cause.

"Again, place in a pond a cylinder of any material, tapering towards each end, and so weighted as (when in the water) to be immersed one-half of its diameter. Suppose the cylinder to be one inch in diameter and twenty-four inches long. Then let the waves be half an inch high, but not more, and if the waves are coming in a direction, fore and aft, the cylinder will have no motion, but, if coming beam on, the cylinder will have some vertical motion, and will roll slightly. Now, take two more cylinders the same as the first, and connect them together by cross-bars on the top only, and let the cylinders have a clear space between them of three inches (at the centre), thereby forming a kind of pontoon-raft, twenty-four inches long and nine inches wide (amidships); put this raft into the water, and it will neither pitch nor roll; the vertical motion will, moreover, be much diminished, no matter which way the waves may come, always provided that they do not exceed half an inch in height. The reason for this is, that the raft is too long to pitch and too wide (*nautice*, with too much beam) to roll. The cause of the diminished vertical motion will be referred to afterwards. Now, increase the dimensions of the cylinders, make them one foot diameter and twenty four feet long, try them with waves not exceeding six inches in height, and the result will be precisely the same as in the first case. If the cylinders are increased in diameter and the size of the waves is increased in proportion, there will always be the same result. In short, the motion of the waves can only be counteracted by the size of the vessel subjected to their action. If the vessel be long enough and wide enough, it will neither roll nor pitch. It is quite true, that if a ship were built according to the present system, with the length proportioned to the breadth, in the ratio of twenty-four to nine, the extreme speed likely to be obtained under the most favorable circumstances would be one knot per hour, but this question of speed will be considered further on. The present proposition is, that if the vessel be constructed long enough and wide enough, it will neither pitch nor roll.

"In the heaviest seas known in the Channel, between Dover and Calais, the waves run fourteen feet high. In order to remain steady in such a sea, a ship should be 600 feet long and 228 feet beam. A structure having these pro-

portions will lie as quietly on waves fourteen feet high as though at anchor in Dover Harbor."

Mr. Egerton's Leviathan is therefore to be built on this principle, which is well illustrated by the working model to which we have referred. We would prefer not to fully endorse the inventor's estimate (fifteen knots an hour) of the speed to be obtained by his vessel, as though the model sails very well, the friction of a full-sized vessel is by no means proportionate to that of a model. Three pontoons in water-tight compartments, and shaped on the lines of a fast-sailing yacht, each fitted with two huge paddle-wheels, are connected by twenty-eight transverse girders, such as are used for bridges. The strength of this structure is simply a matter for engineering calculation, and there can be no difficulty in meeting all necessary requirements on this score. A deck upon the girders, another on their lower sides, and such intermediate ones as are needed, and the whole design is before the mind. The pontoons are one-third longer than the the deck above, so that one-eighth of their length projects at each end. No steering apparatus is needed, as any one of the three engines can be slowed or reversed at pleasure, and as was proved by the model the vessel can spin upon its center as readily as a teetotum, or the *Popoffka* itself.

Apart from the commercial aspects of the project, the chief objection to the employment of vessels of such a size is, the necessity of building special harbors for them. This objection is ingeniously met by the statement that no harbors whatever are required, but only a right-angled pier, to which the Leviathan can come end and broadside on, so that trains may be run direct upon it. The dimensions given above are expressly adapted for the highest wave in the English Channel, namely, fourteen feet, and it is claimed that a vessel of this type would rest as quietly upon such waves as if she were in dock. For further details respecting both construction and cost, we must refer our readers to Mr. Egerton's pamphlet on the subject, simply saying that the estimated cost of a ferry-boat for service between Dover and Calais is £100,000.

Another suggested application of such boats as this is towards the solution of what is truly one of the most serious problems of the day, namely, the transport of live cattle from America and Australia, where they are of but little value, to our own shores, where they are so much needed. The inventor, as an old colonist, is fully alive to this, and he has favored us with calculations to show that a most remunerative trade might be done in this direction. We shall be glad to find these anticipations justified, but for the present we can do no more than give our readers some idea of the ingenious proposals put forward by Mr. Egerton, and leave them to be discussed upon their merits.—*Iron.*

BOOK NOTICES.

IRON HIGHWAY BRIDGES. By ALFRED P. BOLLER, C. E. New York: Wiley.

Mr. Boller, in writing for the benefit of amateurs and engineers of limited training, has done a good service.

HAND-BOOK OF ELECTRICAL DIAGRAMS AND CONNECTIONS. New York: The Graphic Company. For sale by Van Nostrand. Price $1.50.

To all interested in Telegraphy, this book of diagrams will prove attractive, and, doubtless, valuable. Full-page illustrations of the different *repeaters, switches, connections*, etc., including the latest inventions, are given, in very neat form, and with special reference to the elucidation of the principle of action. There are thirty of these plates, besides several smaller cuts exhibiting different forms of battery.

Only so much text is included as serves to briefly describe the diagrams,

A map of the World's Cable Service closes the volume.

TREATISE ON THE MECHANICAL THEORY OF HEAT, AND ITS APPLICATIONS TO THE STEAM ENGINE, ETC. By R. S. MCCULLOCH, C. E. New York: D. Van Nostrand.

This work begins with a historical chapter. A brief sketch of the theories and labors of Huyghens, Young, Fresnel, Rumford, Davy, Carnot, Mayer, Thomson, Clavsius, Joule, Tyndall, and Maxwell, is neatly and concisely given.

The second and third chapters deal with Dynamics. Starting with Bartlett's general equation of energy, the author proceeds to deduce a system of thermodynamics; nothing could be better as an exercise for students of physics than to thoroughly master this portion of the book.

Chapter Fourth presents General Laws; Chapter Fifth, Airs and Vapors; Chapter Sixth, Internal Energy; Chapter Seventh, Air Engines.

In Chapter Eighth, the author, treating of Thermal Laws, has presented a beautiful generalization of these laws which applies to all states of matter. It is a treatise complete.

The applications of these principles fill the remaining chapters, four in number: Steam, Steam Engines, and Miscellaneous Applications, are discussed in turn, and all with remarkable conciseness.

For the scientific student, who is familiar with the Calculus, there is no book known to us that can compare favorably with this treatise. We look for a widespread demand for it as a scientific text book.

TRAMWAYS: THEIR CONSTRUCTION AND WORKING. By J. E. and A. DOWSON. London: 1875. For sale by Van Nostrand. Price $1.50.

Tramways have had a hard fight for it; but they may now be considered to have established themselves as an abiding element of street traffic in large towns, and there is no apparent reason why they should not also be introduced into populous country districts. By and by, too, steam or some other mechanical motive power will doubtless be applied to tram-car traction. The original form of the metals was extremely inconvenient, and that

enabled the opposition of omnibus companies and of other interested and non-progressive interests to triumph for a time in the metropolis; but the form of the rail was improved, and various other imperfections were remedied. A book like the present, in which information is gathered from all parts of the world, must smooth the way to a farther advance. The authors treat successively of the construction and equipment of tramways, their working expenses and maintenance, of mechanical motive power, working of traffic, checking receipts, &c., adding in an appendix some tables of statistical returns and other particulars of tramways in America. Some of the information regarding the checking of the receipts is very curious. The dishonest ingenuity of the conductors seems generally to baffle the most ingenious checks. In the United States it was found that a glass fare box would sometimes double the traffic returns.

RUDIMENTS OF GEOLOGY. By SAMUEL SHARP, F. S. A., F. G. S. Second Edition. London: Edward Stanford.

The author of this little manual, which is designed for the use of schools and junior students, has evidently taken considerable pains to make his work fairly represent the existing state of geological knowledge. He has, moreover, succeeded in conveying in simple language an idea, not only of the conclusions attained, but of the process of investigation and reasoning, followed by the geologist in his researches, and we regard the book as well adapted to introduce a beginner to the study of the science, and to prepare him for the profitable perusal of more extended treatises. As compared with some of the similar introductory text-books of the science, which have recently been published, Mr. Sharp's manual labors under the disadvantage of being somewhat inadequately illustrated, for we find in it only a few diagrams, and no figures of fossils. This second edition, however, is certainly a considerable improvement upon the first, and the division of Physical Geology has received much more full and careful treatment; the extent of the additional matter being sufficient to increase the number of pages of the book from 126 to 204.—*Nature.*

ON FERMENTATION. By P. SCHUTZENBERGER, Director at the Chemical Laboratory at the Sorbonne. With twenty-eight illustrations. Henry S. King & Co., 1876. For sale by D. Van Nostrand. Price $1.50.

The work on fermentation is one of the International Scientific Series. Starting with a thoroughly philosophical conception of his subject, the author points out that from our present stand-point of knowledge, all those phenomena classed together under the name fermentation, are but special cases of the chemical phenomena of life. To life, however, we are not to attribute any extra-material force or influence. Though the force that can reduce the complex chemical edifice called sugar in a certain determinate direction, is manifested only in the living cell of the ferment, yet this "is a force as material as all those we are accustomed to utilize." "In other words, there is really no chemical vital force. If living cells produce reactions which seem peculiar to themselves, it is because they realize conditions of molecular mechanism which we have not hitherto succeeded in tracing, but we shall, *without doubt*, be able to discover at some future time." In the book will be found a clear and concise statement of our present knowledge of fermentation, and a brief history of the progress of opinion and research. The outstanding questions (and there are many) and diverse opinions are presented with scientific impartiality, as is also contradictory evidence. It is gratifying to observe how such rival theories as those of Liebig and Pasteur on the nature of fermentation can be swallowed up in a larger conception, and one at least of the combatants conclude that both may be right. "Fermentation," says Liebig, "is a movement comunicated by instable bodies in process of chemical transformation." "I maintain," says M. Pasteur, "that the chemical act of fermentation is essentially a phenomenon correlative to a vital act." "So be it," replies Liebig, "'a vital act' is a phenomenon of motion; your special views fall within my theory." Necessarily large space in this work is given to the extensive and splendid researches of M. Pasteur, whose views the author follows in the main, though not at all times able to find them quite self-consistent or consistent with admitted facts. On the great question of most general interest—What is the origin of ferments? he adopts the conclusions of M. Pasteur.

A PRACTICAL TREATISE ON ROADS, STREETS, AND PAVEMENTS. By Q. A. GILLMORE, M.A., &c., &c. New York: D. Van Nostrand. Price $2.00.

This practical treatise is by Lieutenant-Col. Q. R. Gillmore, of the U. S. Corps of Engineers, who is favorably known in this country as well as America by his works on cements, and natural and artificial building stones. It contains a good deal that is of course familiar to English readers, and some matter of little use to them; but there is nevertheless much in it interesting and instructive, and it should find a fair circulation among English engineers and borough surveyors.

Col. Gilmore sets out with a review of the considerations which should govern an engineer in locating the line of a new road, and gives some useful hints on the best means of reconnaissance, the use of the pocket aneroid, maps, &c. Some useful formulæ for determining grades and calculating dynamical resistances are introduced, gathered from good authorities, and directions laid down for the drainage of roads and the construction of culverts and catchwaters. In the chapter on road coverings the author alludes to "corduroy" and "plank" roads, which, though well known in the United States, are never heard of here. There are, however, probably some country districts where a corduroy road even would be preferred by the inhabitants to a marsh or swamp, and it is very cheaply and

easily constructed. Straight logs of timber either round or split, are laid down across the road close together, care being taken that the joints or openings between them shall be as small as possible. To reduce the resistance to draught and the violence of the shocks to which vehicles are subjected on such roads, it is usual to level up between the logs with smaller pieces of the same length, but split to a triangular cross-section. These are inserted edge downwards in the open joints, so as to bring their top surfaces even with the upper sides of the large logs, or as nearly so as practicable. Upon the bed thus prepared a layer of brushwood is put, with a few inches in thickness of soil or turf, and the road is complete. Cross drains or culverts are easily made by the omission of two or more logs, the openings being edged with planks, split rails, or poles, laid transversely to the axis of the road and resting on cross beams notched in the logs on either side. Plank roads are simply planking laid down on parallel rows of sleepers or stringers, about five feet apart between centres. The cross-planks are generally about three or four inches thick, and eight feet long, and are so adjusted that their ends shall not be in a line, but form short offsets at intervals of two to three feet, to prevent the formation of long ruts at the edges of the road. New plank roads possess many advantages for heavy haulage as well as for light travel, but the planks soon become worn and warped, and get displaced, and the road is quickly knocked to pieces. Plank roads are a popular and desirable makeshift in newly settled districts where lumber is plentiful, but a common gravel road is mostly preferable.

The methods of constructing gravel and MacAdam roads are treated of a length by Colonel Gillmore. Among other novel substitutes for stone and gravel in some districts in the United States where they are not to be found, he mentions oyster-shells and charcoal. Oyster shells are frequently used on the South Atlantic and Gulf coasts. They wear more rapidly, of course, than stone or gravel, but they are very cheap, and when laid, eight or ten inches thick, directly upon the sandy soil, form a moderately good road for light traffic. A charcoal road is a novelty even in America, but a good road was made of this material through a swampy forest in Michigan. Timber from six to eighteen inches thick was cut twenty-four feet long, and piled up lengthwise in the centre of the road, about five feet high, being nine feet wide at the bottom and two at the top, and then covered with straw and earth. The earth required to cover the pile taken from either side left two good-sized ditches. The timber, when fired, though not split was easily charred, the earth was removed to the side of the ditches, the charcoal raked down to a width of fifteen feet, leaving it two feet thick at the centre and one at the sides, and the road was finished. The material was found to pack well, not to form into ruts nor get soft and spongy in wet weather, although the water was not drained from the ditches. Its cost was only 660 dollars per mile, and in two instances in Wisconsin similar roads were made by contract at 499 and 520 dollars per mile respectively.

With regard to town pavements we have probably little to learn from the Americans. Even in New York cobbles are still extensively used, and their employment throughout the country is general. In New York, as in London, scores of pavements have, of course, been introduced by rival patentees, some of whom have even familiarized ourselves with their inventions. Colonel Gillmore's conclusions are almost identical with those of Mr. Haywood, the Surveyor to the City of London, who is probably the best authority in England on the matter of road materials; shortly stated, they are to the effect that no one pavement combines all the qualities most desirable in a street surface. Asphalt, stone, and wood have all their merits, and may be placed first, second, or third in order of merit, just as local needs and other circumstances are taken into account.

The conclusion of the treatise is devoted to some very useful tables of particulars of some of the American street railroads.—*Building News.*

MISCELLANEOUS.

FLAGSTONE.—A stone passed through Indianapolis from the Greensburg quarries to the Centennial, which was twenty feet eight inches long, ten feet four inches wide, and six feet thick, containing two hundred and thirteen and a half superficial feet. This is probably the largest flagstone ever shipped in the State.

THE RIGHT TO DRAWINGS.—Recently a builder sued an architect in the Sheriff's Court, Glasgow, to recover the working-drawings and calculations for a building erected by the plaintiff, and for which the defendant had been paid. The architect pleaded the custom of the profession, that the architect has a right to all drawings, and introduced evidence to that effect. The sheriff ruled that the custom had not been proven, and ordered the immediate delivery of the drawings to the plaintiff.

ASPHALT, pine flooring, "patent ice," and all other substitutes for the real thing in skating rinks, must give way before the newly-invented ice rink of Professor John Gamgee, of Chelsea, if all be true that is said about it. He is declared to have succeeded in his attems to manufacture by artificial means a perfect sheet of solid ice, which can be maintained constantly so as to bear skaters all day and all night long, if necessary. The ice is produced from below by a refrigerating machine, and the members of the London Skating Club who have skated on the rink already formed pronounce it to be the hardest and best they have ever tried. A very extensive rink can be maintained, it is alleged with a consumption of about fifty-six lbs. of coal per hour. It is claimed for the ice produced by this method of Professor Gamgee's that it has no tendency to produce cold injurious to the feet, but it dries the warm air above, without producing an unpleasant or appreciable sensation of cold. We are curious to see how the patentees of the roller skates will welcome Professor Gamgee's invention.

Some experiments have recently been made at Trieste with a view to testing the intensity of colored lights, and of white light with different oils. While no doubt was entertained that the best effect with lights at a distance was had with white light, and the next best with red, it was desired to ascertain the comparative utility of other colors for harbor lights. Small hand lanterns were used with white, red, deep green. and dark blue glasses. With the white were used American petroleum, paraffine and olive oil. At half a mile distance the dark blue was quite invisible, and the deep blue hardly visible, showing their uselessness for illumination at sea. According to the *Journal of the Franklin Institute* the experiments made to a distance of two nautical miles gave the following results:—(1) That white light with petroleum is more intense than with paraffine; the latter also went out several times, so it lacked the necessary certainty. (2) That among the lights with olive oil the red was the brightest—after the white—and the green, Bohemian make, after the red. The green light may at short distances be made to alternate with the white.

Mr. William Haywood, the City Surveyor of London, has published a report to the City Sewer Commission on Captain Liernur's pneumatic system of sewerage. He reviews briefly the previous existing systems of removing sewage, as in use in this country, glancing at the methods adopted for sewer ventilation, disinfection of sewage, its application to land by means of sewage farms, and their results generally. He then describes Captain Liernur's system, which, as our readers know, consists principally in the adoption of impermeable sewers for rain water, with porous pipes for soil drainage conected with the impermeable rain-water sewers, and the ultimate conversion of all excreta into a dry *poudrette*. Mr. Haywood thinks the system, though complicated, is a feasible and practical one, that by it the solid and much of the liquid matter can be saved for agriculture, that it cannot pollute the soil, and that by its adoption the existing difficulty of sewer ventilation will be met and the consumption of water in towns reduced. On the other hand, the streams will still be polluted by much dirty rain and waste water, and the cleanliness of our present water-closet system would have to be surrendered. Mr. Haywood thinks the system is well worth a fair trial in England, and suggests an opportunity in connection with some of the improved artisans' dwellings likely soon to be erected in the metropolis and elsewhere.

At a recent meeting of the French Academy, M. Lecoq de Boisbaudran communicated some further facts regarding the new metal gallium. The specimens he had formerly presented owed its solidity to the presence of a small quantity of foreign bodies. Pure gallium, of which he had now prepared nearly ten centigrammes, melts at about 29°.5 C.; hence it liquefies when it is seized between the fingers. It is very easily held in superfusion, which explains how a globule has been kept liquid for weeks in temperatures descending occasionally almost to zero. Electrolyzed gallium from ammoniacal solution is identical with that obtained from potassic solution. Once solidified, the metal is hard and resistant, even at a few degrees under its melting point; but it can be cut, and has a certain malleability. Melted gallium adheres easily to glass, on which it forms a beautiful mirror, whiter than that produced by mercury. Heated to a bright red in presence of air, gallium oxydizes but very superficially, and does not volatilize; it is not sensibly attacked in the cold state by nitric acid, but in heat the solution operates with liberation of nitrous vapors. The density of the metal (determined approximately from a specimen weighing sixty-four milligrammes) is 4.7 at 15°, and relatively to water at 15°. The mean of the densities of aluminium and of indium is 4.8 at zero. Thus the density confirms theoretical prevision, while the extreme fusibility is a fact completely unexpected.

Ventilation in France.—General Morin, Director of the Paris Conservatoire des Arts et Metiers, at the Science Conference at South Kensington, described the various systems adopted in hospitals, *crechs*, schools, and other public buildings in France and in St. Petersburg, including the arrangement which depends upon a *chambre de melange* for the mixing of hot air with cold before admitting either of them into the room. He disavowed the means ingeniously devised by M. Daniel Collodon for ventilating the St. Gothard Tunnel. In the salles of the Corps Legislatif tubes beneath the floor opening by orifices not quite beneath the members' seats are largely employed. In a large glass-roofed apartment of M. de Rothschild, at Ferrieres, the air which a glass roof sends down in a freezing state in winter is warmed by a number of jets of gas. Different numbers of cubic meters of air per hour are required for different purposes. In hospitals, for ordinary illnesses, sixty to seventy cubic meters per hour must be admitted for each patient; the wounded require one-hundred meters each; persons suffering from epidemics 150. In prisons fifty meters are enough. In ordinary workshops sixty meters are enough, in unhealthy trades 100 metres are required per hour. In barracks, by day thirty; by night from forty to fifty. In theatres forty, in assemblies sixty. In schools children require twelve to fifteen meters, adults twenty-five to thirty. In stables and stalls the volume required is 180 to 200 metres. Great losses were occasioned in the Mexican expedition by insufficient ventilation for the horses sent out before the ship *Calvados* was fitted up with proper appliances. General Morin concluded by exhorting ladies who preside over *salons* to preserve the health, beauty, and cheerfulness of their guests by abundant supplies of pure air.—*Architect.*

A new aniline dye stuff is said to have been discovered by Dr. Baker, in Brooklyn, which, when mixed with different mordants, produces a brilliant cochinilla scarlet or a dark purple, as well as a jet black color. It is announced as the first aniline dye stuff producing such different colors, and its cost is stated at about 50s. per cwt.